THE EFFECTS OF A SOCIOScientIFIC ISSUES INSTRUCTIONAL MODEL IN SECONDARY AGRICULTURAL EDUCATION ON STUDENTS’ CONTENT KNOWLEDGE, SCIENTIFIC REASONING ABILITY, ARGUMENTATION SKILLS, AND VIEWS OF THE NATURE OF SCIENCE

By

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To my son and his future classmates
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<td>Agricultural, Food, and Natural Resources</td>
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<td>APLU</td>
<td>Association of Public and Land-grant Universities</td>
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<td>IBI</td>
<td>Inquiry-based Instruction</td>
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The effects of a socioscientific issues instructional model in secondary agricultural education on students’ content knowledge, scientific reasoning ability, argumentation skills, and views of the nature of science

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The purpose of this study was to determine the effects of a socioscientific issues-based instructional model on secondary agricultural education students’ content knowledge, scientific reasoning ability, argumentation skills, and views of the nature of science. This study utilized a pre-experimental, single group pretest-posttest design to assess the impacts of a nine-week unit that incorporated a socioscientific issue into instruction on secondary agriculture students’ agriscience content knowledge, scientific reasoning ability, argumentation skills, and views of the nature of science. The population for this study was Florida’s secondary students enrolled in agricultural education. The accessible population was students enrolled in Agriscience Foundations classes in Florida. A convenience sample of Florida’s Agriscience Foundations teachers attending a summer professional development or Chapter Officer Leadership Training session was taken.

Paired-samples t tests were conducted to determine the impact the treatment had on students’ agriscience content knowledge on distal and proximal assessments, as well as on students’ scientific reasoning ability, argumentation skills related to number of
argumentation justifications and quality of those justifications, and views of the nature of science. Paired-samples t tests were also conducted to determine whether the treatment yielded results with middle school or high school students.

Statistical analysis found significant improvements in students’ agriscience content knowledge, scientific reasoning ability, and argumentation skills. High school students’ scores resulted in significant improvements in proximal content knowledge assessments and argumentation justification quality. Middle school students’ scores resulted in significant improvements in proximal content knowledge assessments and scientific reasoning ability. No significant difference was found between students’ views of the nature of science before and after the treatment.

These findings indicate that socioscientific issues-based instruction can provide benefits for students in agricultural education. Teacher educators should work with teachers to maximize the learning that can occur through the various aspects of socioscientific issues-based instruction. Curriculum focusing on socioscientific issues-based instruction should be developed for specific courses in agricultural education. Finally, further investigation should be conducted to better understand how the aspects of socioscientific issues-based instruction can be altered to further enhance student learning.
CHAPTER 1
INTRODUCTION

The nation has been experiencing a shortage of qualified agricultural science graduates to fill the estimated 13,000 annual job vacancies in agricultural, food, and natural resources (AFNR) (USDA, 2005). Approximately 40-45% of the industry’s applicants have been graduates from “allied higher education programs such as biological sciences, engineering, business, health sciences, communication, and applied technologies” (USDA, 2005, p. 3), while just over half of the applicants that graduated and pursued careers in AFNR did so from agriculturally-based majors (USDA, 2005).

Recognizing the need for employers to hire scientifically literate graduates, the USDA recommended that students seeking future employment in agricultural and natural resources have “basic science skills and the ability to solve problems with scientific applications” (USDA, 2005, p. 12). The Association of Public and Land-grant Universities (APLU) (2009) concluded that the development of a system-wide curriculum model to address the scientifically-oriented employment trends of the industry can assist in preparing more students for careers in agricultural sciences. In an effort to better prepare agriculture students for careers in agricultural sciences, this study examined the effect of a socioscientific issues (SSI)-based instructional model on four components of secondary agriculture students’ scientific literacy.

Chapter 1 will describe the industrial and employment trends in the agricultural industry as they have evolved to meet an increasingly scientific environment, as well as recognize agricultural education's well-situated position to teach scientific literacy skills using scientifically-based agricultural issues. Finally, SSI-based education will be
introduced as a potential method for enhancing student scientific literacy in agricultural education.

**Employment Trends in Agriscience**

**The Changing Agricultural Industry**

The gap between AFNR career needs and agriculture graduates’ capabilities has not been without reason; the agriculture industry has changed drastically over the past century, altering the skills and qualifications needed to succeed in AFNR careers. Students receiving education in agriculturally-based fields and principles traditionally have prepared for careers in production agriculture, as farming was previously the most prominent agricultural career (Drache, 1996). Over the past century, however, technological innovations have enabled more people to pursue careers outside of production agriculture (Dimitri, Effland, & Conklin, 2005; Drache, 1996; National Research Council, 2009).

Early 20th century agricultural production took place on a large number of small, diversified farms, where nearly half of the national population was employed (Dimitri, et al., 2005). Technological innovations have increased the efficiency of farm production over the past century, which required a smaller agricultural production workforce to supply the 1996 U.S. population of 260 million consumers than was required to supply a population of 5.3 million in 1800 (Drache, 1996). Over the past century, the declining demand for workers in agricultural production has allowed for more people to seek employment outside of production agriculture, as has been seen in employment and residential trends. Between 1910 and 1930, the number of people living on U.S. farms decreased by one half million, while the national population increased by 31 million (Hopkins, 1973). By 1985, only 2.2% of Americans lived on farms, an approximate 28%
decrease from 1920 (Dimitri, et al., 2005; National Research Council, 1988). Individuals holding farming occupations followed a similar decline; farming has recently represented approximately 1.4% of the Gross National Product and employed 1.5% of the national labor force (Drache, 1996).

While the prominence of farming as a leading occupation has declined over the last century, the agriculture industry as a whole has continued to be a cornerstone of the U.S. economy (Dimitri, et al., 2005). The agricultural industry has recently made up nearly 16% of the Gross National Product; however, only approximately 10.4% of that industry has been made up of production agriculture (Drache, 1996). Agriculture’s ability to remain a leader in the national economy amid shifting workplace trends has been due to its development into a technologically sophisticated industry (Dimitri, et al., 2005; Drache, 1996; Shelly-Tolbert, Conroy, & Dailey, 2000). Between 1975 and 1989, the number of farmers decreased, but the number of farm-related workers increased by 5.1 million (Drache, 1996). As scientific and technological advancements have enabled higher yields to be produced with greater efficiency (Dimitri, et al., 2005), various associated professional careers have developed to support production agriculture, requiring more individuals to pursue careers in supporting areas of agriculture and fewer to engage in production (National Research Council, 1988).

As displayed in Figure 1-1, the range of agricultural careers needed to support the national agricultural infrastructure has continued to diversify and expand to include natural and social sciences, including “scientists, seed suppliers, crop insurers and bankers, food chemists, ethanol producers, packaging engineers, food safety and quality control experts, agro-ecologists, veterinarians, meat inspectors, risk assessors,
contract negotiators, shippers, grocery and retail suppliers, institutional food buyers, and on and on” (National Research Council, 2009, p. 2), and has employed a significant amount of the national labor force (National Research Council, 1988). These aspects of the agricultural industry have recently incorporated genomics, ecology, chemistry, engineering, and other sciences (National Research Council, 2009). One of the driving forces of change in the agricultural industry has been the trend toward scientific innovations to increase agricultural efficiency and minimize risks to human health and the environment, terming this generation the era of scientific agriculture (National Research Council, 2009).

Scientific Agriculture

While the agricultural industry has been experiencing an era particularly focused on its scientific aspects, agriculture has always been rooted in scientific principles, as it consists of biological processes (Federico, 2005; Hillison, 1996; National Research Council, 1988; World Development Report, 2008). Farmers sought scientific research that could be used to increase agricultural productivity in the 1800s, resulting in the passage of the Hatch Act of 1887 (Hillison, 1996). Through the Hatch Act, agriculturalists were able to receive funding to develop “the type of scientific research that brought about an agricultural revolution which still provides the world’s greatest supply of food that is also the most inexpensive and of the very best quality” (Hillison, 1996, p. 8).

Following the passage of the Hatch Act, those responsible for teaching agriculture were required to have a knowledge of science, as well as teach the science of agriculture in connection with its processes (Hillison, 1996), as agricultural education was designed to instruct future farmers in "chemistry, geology, botany, zoology,
mechanics – embracing, in short, the science as well as the practice of agriculture” (Chamber’s Encyclopedia, 1889, p. 61). The notion of agriculture as a science led to the development of the term “agriscience” (Shelly-Tolbert, et al., 2000), which verbalizes the connection between the scientific concepts and physical practices of agriculture. The evolving scientific research in agriculture has continued to “increase crop yields, improve livestock health, reproduction, and growth; and develop new strategies to reduce production costs” (National Research Council, 1988, p. 53). From 1945 to 1994, these technological developments increased agricultural productivity by 1.6% annually (Drache, 1996), which have continued to fuel economic growth (Federico, 2005).

Beginning in the 1980s, advancement in agricultural production has largely been the product of biotechnological research, making the field of biotechnology just as important in agriculture as it is in other fields, such as medicine (World Development Report, 2008; Drache, 1996). The biotechnologies fit into generations:

The first-generation biotechnologies include plant tissue culture for micropropagation and production of virus-free planting materials, molecular diagnostics of crop and livestock diseases, and embryo transfer in livestock... The second-generation biotechnologies based on molecular biology use genomics to provide information on genes important for a particular trait... The most controversial of the improved biotechnologies are the transgenics, or genetically modified organisms, commonly known as GMOs (World Development Report, 2008, p. 162-163).

Much of the advancement in agriculture has been fueled through the third generation of biotechnology, focusing on genetic engineering (Federico, 2005). The biotechnological focus of the industry has carried over to legal issues as well; the 1970 U.S. Plant Variety Protection Act and the 1980 decision regarding patent rights, which essentially permitted patents to be obtained on “almost any genetic creation” (Drache, 1996, p. 3) have further fueled the scientific advancements in agriculture. The American
Association for the Advancement of Science has identified genetic engineering as “one of the four major scientific revolutions of this century” (Drache, 1996, p. 378), implying that scientific agricultural advancement holds great impact on the nation’s future.

Beginning with the release of the Flavr-Savr tomato as the first commercially available genetically engineered variety in 1994 (Federico, 2005), the use of genetically modified varieties has spread worldwide, with over 100 million hectares of crops (approximately 8% of the world’s cropped area) planted in transgenic crops, and new genetically engineered varieties have been approved for field testing every year (World Development Report, 2008). Many have considered genetic engineering in agriculture to be capable of solving world hunger problems:

Biotechnology and information technology have the potential – already realized in some cases – to improve agricultural productivity and fundamentally alter the characteristics of food and fiber products and production processes. Embryo transfers, gene insertion, growth hormones, and other technologies stemming from genetic engineering will result in dairy cows that produce more milk while consuming less feed and livestock that grow faster with fewer pounds of feed. By the end of this century, biotechnology will allow some major crops to be altered genetically so that they become naturally resistant to the diseases and insects that now force farmers to treat crops with pesticides. Other developments will make possible crops with the ability to produce a higher level or quality of protein, manufacture their own plant nutrients, and suppress weeds and insects (National Research Council, 1988, p. 53).

While the above prediction was made over 20 years ago, the world’s growing population and static land resources have implied that scientific advancement in agriculture still plays a major role in the development of food production methods capable of feeding the growing demand (World Development Report, 2008).

Scientific advancement in agriculture has not been without its barriers. While transgenic research holds potential for great strides to be made in overcoming human hunger and malnutrition, the controversial nature of genetic engineering may thwart
scientific agricultural development (Federico, 2005; World Development Report, 2008).

Since the 1960s, public concern regarding the impact of agricultural practices on the environment, animal welfare, and human health has influenced the direction of agricultural research (Drache, 1996; World Development Report, 2008). In recent years, much of this public concern has centered around transgenic technology (World Development Report, 2008). Research and development in agriculture is required in order to continue to meet productivity demands while addressing the multi-faceted issues facing the agricultural industry, including environmental and health challenges, all while maintaining the accountability required by the public (Federico, 2005; National Research Council, 2009).

**Employment in Today’s Agriculture**

Scientific advancements in agriculture have not only contributed to the industry’s productivity, but also its efficiency. Fewer laborers are needed in production agriculture today, while there is increasing need for individuals pursuing careers in supporting areas of agriculture (Shelly-Tolbert, et al., 2000). The supporting areas of agriculture have needed a different set of skills than was previously sought in agricultural production careers (Drache, 1996; National Research Council, 2009), causing employers to seek graduates with skill sets outside those traditionally taught in colleges of agriculture (National Research Council, 2009).

Skills in demand among today’s agricultural employers have directly reflected the challenges facing agricultural development, requiring employees to have concern for the environment, an interest in global perspectives, and rigorous scientific preparation, as well as other transferable skills needed to succeed in non-production agricultural fields, including “problem-solving, critical thinking, team-building, leadership, communication,
conflict and financial management, and thriving in diverse environments” (National Research Council, 2009, p. 18) These skills can be strengthened through education and practice (Phipps, Osborne, Dyer, & Ball, 2008). The current gap between employers’ great need for workers with these skills and the relatively small number of graduates well-versed in them has been well documented (Center for Science, Mathematics, and Engineering Education Committee on Science Education K 12, & NetLibrary, 1998; Harvard Graduate School, 2011; National Research Council, 2009) and has called for new approaches to education in an effort to “focus more on the development of such 21st century skills as critical thinking, problem solving, creativity and communication” (The Conference Board, Corporate Voices for Working Families, Partnership for 21st Century Skills, & Society for Human Research Management, 2006, p. 4). Essentially, these reports called for the development of scientific literacy.

Scientific Literacy

History of Scientific Literacy

The current definition of scientific literacy evolved from the first organized efforts to promote science education in schools (DeBoer, 2000). In the 19th century, scientific and technological advancements drove changes in education, much as they drove changes in the agriculture industry. Education advocates, including John Dewey, considered one of the founders of agricultural education philosophy, claimed that students could benefit through intellectual training focusing on the “inductive process of observing the natural world and drawing conclusions from it” (DeBoer, 2000, p. 582), equipping them with an attitude of independence necessary to participate effectively in society (DeBoer, 2000; Dewey, 1916/1966). Two influential reports, the Cardinal Principles of Secondary Education (National Education Association, 1918) and Reorganization of Science in
Secondary Schools (National Education Association, 1920), made a direct connection between science education and the overall purpose of education, stating that science education should be applicable to daily life activities, which would contribute to the overall purpose of education – to “develop individual…effectiveness in a social world” (DeBoer, 2000, p. 583) The 1945 report of the Harvard Committee on General Education (Harvard University, Committee on the Objectives of a General Education in a Free Society, 1945) further developed the purpose of science education following the direction laid previously by the National Education Association reports. The report recommended that science education include comparisons of science between individual sciences and with other modes of thought, the relation of science in human history, and the prevalence of science in problems of human society (DeBoer, 2000).

The role of science in society and the need for public knowledge and support of science continued to be emphasized by science education advocates, spurred on by the technological advancements of the 1960s, in particular the launching of Sputnik by the Soviet Union (DeBoer, 2000; Laugksch, 1999). Goals of science education became twofold, both providing an adequate supply of qualified scientists needed by society and educating a public on these scientific advancements that were largely supported through public funding (DeBoer, 2000). These became the goals of scientific literacy (DeBoer, 2000), a term that was printed for the first time in Paul Hurd’s 1958 publication, Science Literacy: Its Meaning for American Schools (Laugksch, 1999).

This notion of scientific literacy was identified as the most important goal of science education by the National Science Teachers Association in the 1970s (DeBoer, 2000), and throughout this period into the 1980s, scientific literacy became more closely
aligned with “science in its social context” (DeBoer, 2000, p. 588). The use of scientific literacy in educational policy statements has led to the notion that scientific literacy is a continuing goal of science education (Laugksch, 1999).

**Definitions of Scientific Literacy**

The broad goals of scientific literacy have caused the term to be elusive to precise definition (DeBoer, 2000). Although not universally accepted, the concept of scientific literacy has usually been related to public understanding of science and how the public interacts with science to live more effectively (DeBoer, 2000; Laugksch, 1999). Hazen and Trefil (1991) expanded this definition to include application of knowledge to public issues, as has been seen in both the science-technology-society and socioscientific issues-based educational movements. Miller (1983) attempted to define each of these aspects of scientific literacy through the use of three scientific literacy dimensions, including an understanding of the nature of science (NOS), an understanding of science content knowledge, and an understanding of the relationships between science, technology and society. More specific definitions of scientific literacy have included Showalter’s seven dimensions of scientific literacy, which specify the abilities of scientifically literate people: (a) understand the nature of scientific knowledge; (b) apply science concepts, laws, principles, and theories to the universe; (c) use scientific processes to solve problems, make decisions, and further understanding; (d) interact with the universe in methods consistent with scientific values; (e) understand and appreciate the relationships between science, technology, and society; (f) continue to develop a rich view of the universe through formal science education and lifelong learning; and (g) develop manipulative skills associated with science and technology (Showalter, 1974).
More recent efforts to define scientific literacy have acknowledged that each of the term’s separate definitions is an aspect of scientific literacy (DeBoer, 2000), and that several factors contribute to the appropriate use of a scientific literacy definition (Laugksch, 1999). Laugksch offered a model depicting how these factors interact to create separate but equal definitions of scientific literacy. A consideration of these aspects has led to the development of scientific literacy definitions specifically related to science education in schools. Both the American Association for the Advancement of Science (AAAS) and the National Research Council (NRC) have delineated the purposes, goals, and necessary aspects of scientific literacy in science education, and as depicted in Figure 1-2, align with one another, allowing schools to consult both reports for direction in achieving scientific literacy (Laugksch, 1999).

The definition of scientific literacy provided by the AAAS was originally published in 1989 through its report, Project 2061: Science for All Americans. This report offered statements regarding the goals of science teaching, and was followed in 1993 with the second Project 2061 report, Benchmarks for Scientific Literacy, which specified what students should know and be able to do by certain grade levels in order to progress toward scientific literacy (American Association for the Advancement of Science, 1993/2009). These benchmarks were then updated in 2009, providing one of the most recent directives for achieving scientific literacy. The report included 12 areas of benchmarks, each containing subareas for which grade-level competencies were offered: (a) the NOS, (b) the nature of mathematics, (c) the nature of technology, (d) the physical setting, (e) the living environment, (f) the human organism, (g) human society,
(h) the designed world, (i) the mathematical world, (j) historical perspectives, (k) common themes, and (l) habits of mind.

The National Research Council's National Science Education Standards has offered a definition of scientific literacy for students through content standards that are separated by grade level (National Research Council, 1996). Similar to the AAAS report, the NRC report included standards that were broken down into subareas for which grade-level competencies were offered. Eight content standards were offered for grades 9-12: (a) Unifying Concepts and Processes; (b) Science as Inquiry, (c) Physical Science, (d) Life Science, (e) Earth and Space Science, (f) Science and Technology, (g) Science in Personal and Social Perspectives, and (h) History and NOS. These national standards have served as the primary source for the development of state-level science education standards (Linda Jones, personal communication, 2011).

The Need for Scientific Literacy in Agricultural Education

As stated previously, the scientific components of the agricultural industry have been increasing in depth and complexity; “agriculture now so thoroughly combines basic and applied aspects of the traditional STEM disciplines of science, technology, engineering, and mathematics that the acronym might rightly expand to become STEAM, joining agriculture with the other fundamental disciplines” (National Research Council, 2009, p. 4). As the world population has increased, agriculture has been expected to increase agricultural production and improve the nutritional status of those in need (Federico, 2005).

However, the potential agricultural advancements that can alleviate these upcoming problems have also been suspect to scrutiny by an increased number of eyes as the public has begun to hold more weight in agricultural advancements and practices
Controversies regarding agricultural practices and technologies have stemmed from perceived environmental, food safety, health, and social risks, which have continued to persist, even in light of scientific evidence supporting the safety of such practices (World Development Report, 2008). These controversies have led to the rise of two alternate responsibilities: (a) agricultural production must continue to improve while abiding public demands for decreased environmental, food safety, and health risks (Federico, 2005; National Research Council, 2009); and (b) the public must become scientifically literate in order to make educated decisions regarding agricultural technologies (National Research Council, 2009).

The Need for Educated Consumers

In the past, American consumers have impacted the practices of certain agricultural industries with their preferences (Drache, 1996; Hopkins, 1973). Demand has shifted toward products that offer convenience and health benefits to consumers (Dimitri, et al., 2005; Hopkins, 1973), and consumer concerns for food production risks have caused industries to shift from practices aimed solely at increasing production to those that also address environmental protection, animal welfare, and food purity (Dimitri, et al., 2005). The recent and potential advances in biotechnology have already been thwarted by environmental groups concerned about the possible risks of such science (Drache, 1996), and so the future of agricultural production and aspects of society impacted by agricultural production rely on the agricultural awareness and scientific literacy of the public (National Research Council, 2009).

However, these same agricultural advancements have gradually pushed the general public away from agricultural awareness, as fewer people have direct
experience with agriculture (National Research Council, 2009). Previous studies have documented the current lack of scientific and agricultural literacy among students, leading researchers to recommend that materials be developed to aid in the education of agricultural literacy to all students (Pense, Beebe, Leising, Wakefield, & Steffen, 2006; Pense & Leising, 2004).

This lack of connection with the agricultural industry has impacted both of the goals of scientific literacy: students have been generally unaware of the broad opportunities offered by agricultural careers, leading fewer to pursue agricultural sciences, and they have been incapable of making educated decisions regarding agricultural practices as scientifically literate citizens (National Research Council, 1988; 2009). Publications concerned with agricultural education have met the problems of an ill-prepared workforce and scientifically illiterate consumers with more questions: “Is the next generation of leaders in agriculture prepared to address…critical demands on our agricultural systems?” (National Research Council, 2009, p. 2). Current research on agricultural education, scientific literacy, and workplace needs have suggested not. If that is the case, “with the field of agriculture becoming more sophisticated and scientifically based, how can agricultural education graduates be best prepared for that field?” (Hillison, 1996, p. 12). These questions have appeared to mirror those that generated previous science education reform, calling for an educational focus on scientific literacy.

Preparing Future Consumers through Agricultural Education

As noted previously, scientific literacy has been posited to impact policy decisions (Laugksch, 1999). However, the NRC’s 1988 report, Understanding Agriculture: New Directions for Education, found that students did not receive enough instruction to
prepare them to be scientifically literate. Because the workplace needs in agriculture and the societal needs for educated influence on agricultural policies align with those skills necessary for scientific literacy (National Research Council, 2009), those skills must be emphasized in agricultural education (National Research Council, 1988; 2009; Shelly-Tolbert, et al., 2000). This necessitates the inclusion of societal issues into education, as much of scientific literacy focuses on students’ awareness of science in society (National Research Council, 1996).

While educators were previously criticized for failing to link educational content with real world events (Conroy & Walker, 2000), the National Research Council (2009) posited that agricultural education is “uniquely positioned to respond to students’ interest in making the world a better place and in responding to such important societal needs as food, health, environmental stewardship, sustainability, and energy security” (p. 99). The context of agriculture provides ample opportunity for teachers to incorporate real-world examples and case studies of scientifically-based issues, termed socioscientific issues (SSIs), into instruction, and the current outlook of the agricultural industry suggests that SSIs will continue to be the focus of the industry for the foreseeable future (National Research Council, 1988; 2009), providing agricultural educators with prime real-world contexts for developing student scientific literacy.

**Socioscientific Issues Education**

The notion of SSIs in secondary educational settings stemmed from unrest regarding the disconnect between school science, professional science, and science in society. While many of the concepts behind classroom science have been derived from professional science, those concepts are “translated, simplified, and completely abstracted” from their contextual origin, leading students to have difficulty making the
connection between classroom concepts and professional science” (Sadler, 2009, p. 9). Sadler (2009) recommended that students engage in scientific communities of practice in order to connect classroom concepts with the real world of science; however, a disconnect has also existed between the discourse of professional communities of science and those of real-world, societal science, leaving students with a professional science that is still irrelevant and disconnected from their lives.

Utilizing SSIs connects abstract classroom science with a context appropriate for students' lives and future decision-making responsibilities as scientifically literate citizens (Berkowitz & Simmons, 2003; Sadler, 2009). Just as these citizen-based responsibilities require critical thinking skills, SSI-based instruction requires a problem-solving approach to education which enables students to construct their own knowledge of the SSI’s facets and utilize relevant experiences to make decisions (Phipps, et al., 2008).

SSIs can encompass a wide variety of concepts and contexts, although they share two common elements – a conceptual or procedural connection to science and a level of social significance as identified by the community (Sadler, 2004; 2009; Sadler & Ziedler, 2003). While all science is directly tied with the society in which it was established (Sadler & Ziedler, 2003), SSIs hold a unique standing because they are informed by scientific data as well as by economic, social, political, and ethical considerations (Sadler, 2009; Sadler & Ziedler, 2003). This social significance lends most SSIs to be controversial in nature, and therefore, the subject of debate and concern in everyday life (Chang-Rundgren & Rundgren, 2010; Sadler, 2009). Further, modern advances in technology and science, paired with the environmental and
economic strains of today’s society, “guarantee the prominence of these kinds of issues in the present and future” (Sadler, 2004, p. 513).

Incorporating SSIs into the classroom is appropriate for many levels of science education, including secondary classrooms (Sadler & Ziedler, 2003), as these students will be responsible for reacting to science in the capacity of scientifically literate, engaged citizens in their future (Albe, 2008). However, in order to incorporate SSIs effectively, researchers have recommended various characteristics to identify authentic SSIs.

Chang-Rundgren & Rundgren (2010) developed a collection of agreed-upon features of SSIs based on the works of science education researchers (Albe, 2008; Colucci-Gray, Camino, Barbiero, & Gray, 2006; Fensham, 2008; Sadler, Barab, & Scott, 2007; Simonneaux & Simonneaux, 2009) and identified complexity, multiple perspectives, inquiry, and skepticism as important features. The controversial nature of SSIs is also characteristic, being labeled as “ill-structured problems” by several researchers (Klosterman & Sadler, 2011; Kuhn, 1991; Sadler, 2009; Zohar & Nemet, 2002). According to Sadler (2009), ill-structured problems of science are unique to SSIs, as they “do not have single correct answers, cannot be meaningfully addressed through memorized or well-rehearsed responses and are not subject to relatively simple algorithms” (p. 11). Rather, students engaging in the ill-structured problems of SSIs encounter science-in-the-making (Latour, 1987), as the uncertainty and disagreement between scientists eliminates the possibility of one correct answer (Albe, 2008). Many of today’s SSIs focus on environmental, health, and consumer concerns, and therefore,
are agriculturally-based, allowing agricultural education to provide an ideal environment for SSI-based education (National Research Council, 2009).

**Statement of the Problem**

Scientific literacy is the educational currency by which employment skills are valued and through which individuals can responsibly contribute to societal issues and decisions (American Association for the Advancement of Science, 1993/2009; National Research Council, 1996). The ever-evolving scientific and technological advancements impacting the agricultural industry have called for scientifically literate individuals that possess critical thinking and decision making skills beyond those needed previously (Harvard Graduate School, 2011; National Research Council, 1988; 2009). In light of the impact these advancements have on consumer choices, these same skills of scientific literacy are needed by consumers in order to make educated decisions regarding agricultural developments, as has become a trend in recent years (Drache, 1996).

While agricultural education has been reported to be an ideal setting for the development of scientific literacy skills through applicable contexts (National Research Council, 1988; 2009), the practices in secondary agriculture classes have been slow to change, as the same problems regarding increasing scientific literacy have been the focus of agricultural education reform for over 20 years (National Research Council, 1988; National Research Council, 2009). The NRC (2009), APLU (2009), National Science Education Standards (1996), and the National Research Agenda (Doerfert, 2011) have called for changes in teaching practices in order to improve student scientific literacy, and recommended the incorporation of real-world, societal issues into instruction as a means of improving scientific literacy.
Numerous researchers in science education have reported student improvement in areas of scientific literacy resulting from SSI-based instruction (Albe, 2008; Klosterman & Sadler, 2011; Sadler, 2009; Sadler, 2011; Sadler & Zeidler, 2003). Many of the issues utilized in SSI-based instruction are agriculturally based (Zeidler, Walker, Ackett, & Simmons, 2002), suggesting that SSI-based instruction in secondary agricultural education classes may improve students’ scientific literacy. The problem addressed by this study was the continuing gap between students’ scientific literacy skills and those needed to succeed in the workplace and society (Harvard Graduate School, 2011; National Research Council, 1996; 2009), and the search for instructional methods well-suited for secondary agricultural education that show evidence of success for improving student scientific literacy skills.

**Purpose of the Study**

The purpose of this study was to determine the effect of an SSI-based instructional model on specific aspects of agriscience student scientific literacy, including agriscience content knowledge, scientific reasoning ability, argumentation skills, and views of the NOS.

**Statement of Objectives**

In order to meet the above purpose, several objectives were developed:

- To determine the effects of an SSI-based instructional model on middle and high school agriculture student agriscience content knowledge.
- To determine the effects of an SSI-based instructional model on middle and high school agriculture student scientific reasoning ability.
- To determine the effects of an SSI-based instructional model on middle and high school agriculture student argumentation skills.
- To determine the effects of an SSI-based instructional model on middle and high school agriculture student views of the NOS.
Statement of Hypotheses

Statistical analysis deemed appropriate the use of null hypotheses. The null and alternative hypotheses developed for this study included:

\( H_0^1 \) – There is no significant difference between the agriscience content knowledge of secondary agriculture students before and after experiencing SSI-based instruction.

\( H_A^1 \) – Students experiencing SSI-based instruction will display a change in agriscience content knowledge scores on posttests administered after the SSI-based instruction from scores on pretests administered before the SSI-based instruction.

\( H_0^2 \) – There is no significant difference between the scientific reasoning ability of secondary agriculture students before and after experiencing SSI-based instruction.

\( H_A^2 \) – Students experiencing SSI-based instruction will display a change in scientific reasoning ability scores on posttests administered after the SSI-based instruction from scores on pretests administered before the SSI-based instruction.

\( H_0^3 \) – There is no significant difference between the argumentation skills of secondary agriculture students before and after experiencing SSI-based instruction.

\( H_A^3 \) – Students experiencing SSI-based instruction will display a change in argumentation skills scores on posttests administered after the SSI-based instruction from scores on pretests administered before the SSI-based instruction.
H₀⁴ – There is no significant difference between the views of the NOS of secondary agriculture students before and after experiencing SSI-based instruction.

Hₐ⁴ – Students experiencing SSI-based instruction will display a change in views of the NOS scores on posttests administered after the SSI-based instruction from views on pretests administered before the SSI-based instruction.

**Significance of the Study**

This study holds significance for secondary agriculture teachers seeking appropriate methods of instruction for integrating science into agriculture classes and potentially enhancing student achievement in agricultural and scientific content. SSI-based instruction is currently a well-received instructional method in science education (Sadler, 2009; 2011), but has not yet been introduced in secondary agriculture classes. The results of this study can offer agriscience teachers an introduction to how SSI-based instruction may impact their students’ achievement. Further, secondary agriculture teachers can utilize the instructional materials developed in this study as a starting point for collaboration between themselves and science teachers.

This study also holds meaning for agriculture teacher educators seeking to introduce preservice teachers to instructional methods that can increase student achievement in agriscience. The similar goals of agricultural and science education call for integration of science content into agricultural education (Phipps, et al., 2008; Thoron, 2010), and this study offers an instructional method with potential to better integrate scientific content into agricultural contexts. Agriculture teacher educators can also find this study meaningful when working with inservice teachers, who were not exposed to SSI-based instruction during their preservice teacher education due to the method’s relatively recent introduction to educational practice. When inservice
agriculture teachers are introduced to SSI-based instruction, they can utilize this study and the above methods specifically related to secondary agriculture teachers.

Curriculum developers can also find significance in this study, as several entities currently offer case study scenarios for use in science education (National Center for Case Study Teaching in Science, 2010). This study can be utilized to provide insight in how SSI-based instruction in agricultural education utilizes SSIs, allowing curriculum developers to design curriculum and SSI focus according to these uses.

Finally, this study holds significance for advocates of agricultural education. The National Research Agenda (Doerfert, 2011; Osborne, n.d.) and National Research Council (1988; 2009) call for agricultural education to identify itself as a contributing factor toward student achievement. The results of this study can help quantify how agricultural education may contribute to student achievement, as well as link the goals of agricultural education with the overall goals of secondary education.

**Definition of Terms**

The following terms were operationally defined for use in this study:

- **AGRICULTURAL EDUCATION.** The profession of teaching students in the multi-faceted aspects of today’s agriculture industry (Thoron, 2010).

- **ARGUMENTATION SKILL.** The ability to develop statements to provide support for a decision or conclusion (Halpern, 1989; Thoron, 2010). Components of argumentation include articulating and justifying claims, considering counter positions and evidence, and the social negotiation of data and theories (Sadler & Fowler, 2006). In this study, argumentation skill was defined as the score on a scoring rubric developed by Sadler and Fowler (2006) for specific use with SSI-based instruction.

- **CONTENT KNOWLEDGE.** “Subject matter tested following treatment which measures the level of correct responses from content presented in class from the instructor” (Thoron, 2010, p. 32). Because agricultural education is responsible for educating students on a broad array of content areas, this study defines content knowledge as the content presented to students in the lessons leading up to assessment, including both agricultural and science content.
• **Scientific Literacy.** Public understanding of science and how the public interacts with science to live more effectively, including the application of this understanding to public issues (DeBoer, 2000; Laugksch, 1999). Because of the multi-faceted definition of scientific literacy, student scientific literacy is not measured in a composite manner (DeBoer, 2000; Laugksch, 1999). Therefore, this study defines scientific literacy as those aspects commonly addressed in SSI-based instruction, including argumentation (Sadler & Fowler, 2006; Zohar & Nemet, 2002), scientific reasoning (Sadler, 2004; Thoron, 2010), views of the NOS (Zeidler, et al., 2002), and content knowledge (Sadler & Fowler, 2006; Yaeger, Lim, & Yaeger, 2006; Zohar & Nemet, 2002).

• **Scientific Reasoning.** “The use of the scientific method, inductive, and deductive reasoning to develop and test hypotheses” (Thoron, 2010, p. 33). Because agricultural education is responsible for developing in students a broad range of scientific reasoning skills, Lawson’s Classroom Test of Scientific Reasoning (LCTSR) (1978) was utilized to measure scientific reasoning as defined above.

• **Socioscientific Issues.** Issues utilized as a student-relevant context in education that have a conceptual or procedural connection to science and a level of social significance as identified by the community (Sadler, 2004; Sadler, 2009; Sadler & Ziedler, 2003). The SSI utilized for this study is the development of laboratory-grown meat for human consumption.

• **Socioscientific Issues-Based Instruction.** Instructional techniques designed around an SSI. While SSI-based instruction is designed to be flexible rather than prescribed (Sadler, 2011), this study will follow Sadler’s (2011) framework for developing SSI-based instructional components, including design elements, classroom elements, learner activities, and teacher attributes.

• **Views of the NOS.** The particular ways of observing, thinking, experimenting, and validating used to develop interconnected and validated ideas about the physical, biological, physiological, and social worlds (American Association for the Advancement of Science, 1993/2009). For this study, the Views on Science and Education Questionnaire (VSOE) (Chen, 2006) was utilized to measure seven aspects of views of the NOS deemed to be of particular relevance to K-12 education, including tentativeness of scientific knowledge, nature of observation, scientific methods, hypotheses, laws, and theories, validation of scientific knowledge, and objectivity and subjectivity.

**Limitations of the Study**

The conclusions and implications drawn from this study are subject to the study’s limitations, including:
The study’s convenience sample - The study included a convenience sample of Florida secondary agriculture teachers, and therefore, cannot be generalized beyond the sample in this study.

The study’s pre-experimental design - This study does not include a control group, reducing the validity of any claims stating SSI-based instruction’s effect on outcomes, as well as limiting the ability to compare the results of SSI-based instruction to outcomes of other methods of instruction.

The study’s length - The lengthy duration of the study subjects it to the threat of history, as students will continue to attend science classes as well. These historical factors could impact their scientific literacy achievement and must be considered when interpreting this study’s results. Maturation is also a threat present due to the study’s length, as students will develop cognitively between the start and conclusion of the study.

The researcher-designed instrument - The content knowledge assessments and argumentation scenario were developed by the researcher and therefore pose a threat to the study’s validity. The instruments were reviewed by a panel of experts in agriscience and science instruction for face and content validity and the content knowledge assessments were analyzed for reliability in order to reduce this threat.

Instrument subjectivity - The level of inference required by researchers when utilizing Sadler and Fowler’s (2006) argumentation rubric to analyze argumentation scenario responses limits the reliability of the scores. Following Sadler and Fowler’s (2006) methods, one-third of the responses were analyzed by a second researcher to establish inter-rater reliability.

Fidelity of implementation - Lessons were not delivered by the researcher; multiple teachers delivered lessons, and so potential infidelity of the lessons’ implementation is a limitation to this study. To reduce this threat, teachers were each trained in the use of SSI-based instruction, detailed daily lesson plans were distributed, and the researcher instructed teachers to audio-tape each lesson. Taping sessions were intended to be randomly selected for analysis. However, teachers’ failure to record and submit classroom sessions made analysis implausible.

Teachers’ effect on learning - The use of multiple teachers with different teaching styles, classroom cultures, and relationship dynamics with students could impact student learning, thus limiting the results of this study.

Novelty of teaching method - Because SSI-based instruction and this specific SSI were both new to teachers and students, findings could be caused by a novelty effect. This threat was reduced through the nine-week duration of the study.

Classroom make up - Because students in Agriscience Foundations are not enrolled systematically but can be enrolled because of unique scheduling
situations, the student make up each classroom cannot be assumed to be equal. Individual student differences, as well as classroom differences stemming from the student make up, limit the study’s findings. These limitations were reduced through the use of a pretest-posttest design.

- Assessment delivery - While the lengthy assessments were distributed to teachers in segments, teachers may have been forced to further section off assessments to avoid student fatigue and to coincide with class schedules.

- Intervention delivery - Teachers were originally instructed to complete the nine weeks of provided lesson plans within a twelve-week time frame. However, teachers were unable to do so and requested an extension to fourteen weeks. Additionally, teachers were only able to complete six weeks of the lesson plans, omitting all Animal Industry lesson plans from the study. The variability of lesson delivery time of each lesson within the fourteen-week time frame is a threat to the study’s validity, as students were exposed to uncontrolled learning experiences during the remaining time.

Assumptions of the Study

The following assumptions were made in order to conduct this study:

- Students participating in the study exhibited their skill to the best of their ability.

- Teachers participating in the study accurately delivered the instructional materials according to the SSI-based instructional guidelines.

- The SSI selected for the instruction in this study adheres to the definition of an SSI, is relevant to all students, and is not the focus of agriculture instruction using other instructional techniques.

- Teachers had no familiarity with SSI-based instruction before the beginning of this study and therefore all have had the same professional development regarding SSI-based instruction.

Summary

Scientific literacy skills have been a crucial component required of young adults by today’s agricultural workplaces and decision-making components of society. However, the gap between the need for these skills and individuals’ possession of these skills has indicated that education must better prepare students to be scientifically literate individuals. This study addressed the NRC’s (2009) and National Research Agenda’s
(Doerfert, 2011; Osborne, n.d.) calls for agricultural education’s commitment to promoting scientific literacy and increasing student achievement by evaluating an instructional model designed to integrate science with today’s relevant agricultural issues. Specifically, this study assessed the effect of an SSI-based instructional model on students’ content knowledge, argumentation skills, scientific reasoning, and views of the NOS.

Scientific literacy has been a component of science education throughout its history, essentially being equated with the overall purpose of science education. Definitions of scientific literacy have been multi-faceted and dependent on numerous components, which have led the term to be ill-defined and controversial. Definitions of scientific literacy provided by the AAAS and NRC have most recently offered comprehensive components of scientific literacy, as well as standards for students to meet at specific grade levels. Both of these definitions include an aspect relating to how students utilize scientific literacy in real world problems.

With the agriculture industry’s current spotlight in societal issues due to an increased trend in consumer ownership and constant advancements in science and technology, agricultural education has been considered an ideal setting for teaching science through real world agricultural contexts. SSI-based instruction, while proven to be a useful method in science education, has not been tested in agriculture classes. However, many of the SSIs utilized in science classes have direct ties to agriculture, indicating that SSI-based instruction may be an effective method of integrating science into agriculture classes, while focusing this science on components related to scientific literacy.
This study addressed the need for agricultural education to incorporate science instruction into agricultural contexts through real-world, societal issues. The purpose of this study was to determine the effect of an SSI-based instructional model on specific aspects of agriscience student scientific literacy, including agriscience content knowledge, argumentation skills, scientific reasoning ability, and views of the NOS. The results of this study are meaningful for secondary agriculture teachers, agricultural educators, curriculum developers, and advocates of agricultural education. Chapter 1 provides an overview of the study, operationally defines terms utilized in the study, and identifies assumptions and limitations of the study.

Figure 1-1. The Food and Fiber System (Majchrowicz, 1990)
Figure 1-2. Laugksch’s conceptual overview of scientific literacy (Laugksch, 1999)
CHAPTER 2
REVIEW OF LITERATURE

Chapter 1 detailed the study’s purpose and provided justification for determining the effect of a socioscientific issues (SSI)-based instructional model on student learning, including content knowledge attainment, argumentation skills, scientific reasoning ability, and views of the nature of science (NOS). The goal of Chapter 2 is to provide the theoretical and conceptual frameworks which guided the study. Also included in Chapter 2 is a review of the salient research pertaining to the various aspects of the conceptual framework guiding this study, including teacher formative and training experiences and properties that impact SSI-based education, student formative experiences and properties that impact their learning during SSI-based instruction, the types of experiences had by students during SSI-based instruction, and the short term outcomes of SSI-based instruction.

Constructivism

The grand theory supporting this study was constructivism, which states that all learning is the product of the construction of knowledge through experience (Fosnot, 1996). Several forms of constructivism which differ on the philosophy of reality and social truths exist on a continuum (Doolittle & Camp, 1999). At one end of the continuum, cognitive constructivism focuses on the cognitive processes of the individual learner, and states that the individual can accurately perceive and know the external knowledge. At the other end of the continuum lies radical constructivism, which states that the knowledge constructed by an individual is merely a representation of the external knowledge, but that the external knowledge cannot itself be known by the individual. Between these two extremes lies social constructivism, which states that
knowledge is constructed and shared socially rather than constructed individually and is therefore bound to the setting and place in which it was socially constructed. While there is debate as to with which constructivist form agricultural education historically has or should be categorized (Doolittle & Camp, 1999), teachers must recognize that learning can occur through both individual and social experiences (Roberts, 2006). Further, knowledge constructions can present different meanings to different individuals based on the constructivist premise that people interpret experiences differently, regardless of the experience’s reality or true meaning (Beard & Wilson, 2006; Doolittle & Camp, 1999). These premises, amid others, were identified in Driscoll’s common assumptions of constructivism (1994), stating that: (a) constructivism involves complex, challenging, and authentic tasks; (b) learning is a shared responsibility that occurs through social contexts; (c) individualities lead communities to multiple representations of the same content; (d) that knowledge is not “pre-wired” but rather constructed; and (e) learning must be student centered. When following constructivism’s philosophies and assumptions, Knobloch identified benefits of constructivist learning: (a) students learn to apply and see implications of acquired knowledge, (b) authentic learning environments centered around learners and a social context foster invention and creativity, and (c) students identify that knowledge is organized for appropriate uses in specific contexts (2003).

While the benefits and processes of constructivist education seem natural to learners, providing constructivist instruction has not always been considered. This is not to say, however, that classrooms were void of experience in past instructional settings. By human nature, learning and development cannot occur without some sort of
experience (Beard & Wilson, 2006; Joplin, 1981; Kolb, 1984; Vygotsky, 1978). Dewey (1938) expanded on this point in detail, stating that experiences were present in traditional education, but “the experiences which were had, by pupils and teachers alike, were largely of the wrong kind" (p. 26). Beard and Wilson (2006) also claimed that learners are always experiencing, but not necessarily in the right way, referring to traditional methods of instruction with Freire’s (1982) term of “banking education,” in which teachers deposited knowledge into passive student receptacles.

**Experiential Learning**

In contrast to traditional education, experiential learning, in true constructivist fashion, combines the aspects of experience, perception, cognition, and behavior (Kolb, 1984) to apply knowledge and practice in real situations while modeling appropriate behaviors and procedures (Randell, Arrington, & Cheek, 1993). Specific dimensions of experiential learning include a concrete, authentic experience to be had by learners, active experimentation, internal and/or external reflection, observational learning, abstract conceptualization, risk and responsibility, and the role of the teacher as a facilitator (Knobloch, 2003).

**The Cognitive Aspect of Experiential Learning**

The premise of experiential learning surrounds the idea of the individual and his or her internalization of experiences to develop unique meaning. This occurs at both the social and individual levels (Vygotsky, 1978). As learners acquire knowledge, they add or change neural connections (Beard & Wilson, 2006). These changes in connections affect future learning as new experiences are connected with previous knowledge and experiences (Knobloch, 2003). Connections can be made with previous experience but must be coherent with (or altered to fit) an individual’s beliefs and perceived truths. If
there is a discrepancy between established knowledge and new experiences, the individual will revise theories or reflect on past experiences to fit the new information into established beliefs (Beard & Wilson, 2006). An individual adopts new ideas through either integration, which allows the idea to become a stable part of his or her world conceptions, or substitution, which produces resistance to adoption due to a conflict or inconsistency between the new idea and previously established beliefs (Kolb, 1984). In substitution, learners must accommodate somehow in order to allow initially conflicting theories to exist in their models of reality (Doolittle & Camp, 1999). Drawing out and addressing student beliefs through experience is the responsibility of the teacher, who can utilize these facets of cognition to allow students to adopt new ideas and make accurate connections (Kolb & Kolb, 2006).

The Experiential Learning Cycle

Numerous researchers, including Dewey (1938), Joplin (1981), Kolb (1984), and others have created models of the experiential learning cycle, all displaying certain recurring characteristics. Roberts (2006) identified the similar traits between these three prominent models as indication of a cyclical process, initial focus being on the learner, learner’s direct experience with phenomenon, and the presence of reflection and then development of rules or hypotheses. Each of these similarities can be observed in Kolb’s Model of the Experiential Learning Process (1984) (Figure 2-1). The learning cycle can begin at any of the four stages (Roberts, 2006), but in order for learning to occur, the learner must experience a process involving a method of grasping information and then transforming that experience into new knowledge (Kolb, 1984). Either of these aspects of thought and action alone is not sufficient to produce learning (Cuffaro, 1995), and postponement of action until after thought is key in the learning
process (Dewey, 1938). The cycle involves a learner grasping information, through either a concrete experience (via apprehension) or abstract conceptualization (via comprehension). Once information has been grasped, it is transformed into new knowledge through either reflective observation (via intension) or active experimentation (via extension) (Kolb, 1984).

Typically, the cycle involves each of the four stages, which coincide with Dewey’s steps of learning progression (1910/1997). These involve experiencing a felt difficulty (problem or purpose), identifying the problem’s location and level of difficulty, suggesting of possible solutions, developing by reasoning, and further observing or experimenting. The teacher and learner can work through this process through development of a quality purpose, which requires observation of surrounding conditions, knowledge of learners’ past experiences and the experiences of others, and judgment to combine the observation and past knowledge to determine how they should be interpreted (Dewey, 1938).

**Problem Solving**

A preferred method of experiential learning in agricultural education is the problem solving approach (Parr & Edwards, 2004; Phipps, et al., 2008), which aligns with Dewey’s (1910/1997) learning progression steps. During problem solving instruction, students are provided with new experiences that enable them to develop their own questions through their experiences and then test out solutions to answer those questions. The goal of problem solving is to enable students to “engage in a problem-solving process that is widely applicable in academic, personal, and professional settings” (Phipps, et al., 2008, p. 240), allowing them to be better decisions makers as citizens. Lancelot (1944) recommended that teachers put substantial care into selecting
useful problems for students to solve. Phipps, et al. (2008) recognized that the agriculture industry contains a large number of ill-structured problems, “involving complex scenarios where many possible courses of action (decisions, solutions) are possible” (p. 244). These ill-structured problems can enhance student learning even further by engaging them in SSI-based instruction as a method of problem solving (Sadler, 2004).

**Problem Solving in K-12 Education**

Instruction utilizing problem solving methods is not appropriate in every classroom. According to Piaget (1981), children are only capable of engaging in problem solving in any manner once they progress into the third stage of his theory of cognitive development, titled Concrete Operations. Children entering the concrete operations stage, typically between ages seven and 11, are able to utilize thought processes to solve concrete problems which tangibly exist (Wadsworth, 1996). Once they move into the final stage in cognitive development theory, termed Formal Operations, students have the capability to solve all manner of concrete and abstract problems through reasoning and logic (Wadsworth, 1996).

While students typically develop the structures required to utilize formal operations around age 11 or 12 (Piaget, 1981), numerous studies have reported that “a substantial proportion of the American adult population never advances much beyond concrete operational reasoning” (Wadsworth, 1996, p. 112). Education has been reported to be a useful tool in aiding in the development of formal operations, and has been reported to be more influential in the development of these higher cognitive skills than in the development of more concrete skills (Wadsworth, 1996). Providing social interaction and exploration of an SSI can help students in the concrete operations and
formal operations stages develop skills that are in their zone of proximal development, but not yet mastered (Vygotsky, 1978, Wadsworth, 1996).

**Problem Solving through Socioscientific Issues**

Learning experiences can be enriched in order to enhance student learning (Dewey, 1938) according to the goals of the education (Sadler, 2011). SSI-based instruction improves student learning experiences by allowing them to practice using scientific principles and concepts in situations similar to those they will experience in the future as citizens in a scientific society (Sadler, 2011). Because SSIs involve multiple facets of learning, including scientific principles and processes, consideration of morals and ethics, and political venues (Sadler, 2011), the mere insertion of relevant issues into existing educational practices does not provide students a substantial opportunity for developing scientific literacy. Eilks (2010) offered a five-step model for the operationalization of SSI-based instruction (as cited in Sadler [2009]):

1. Problem analysis. In this step, students are presented with an issue of interest through media reports or other strategies that highlight the reality and relevance of the issue.

2. Clarification of the science. Teachers help students understand the basic science underlying the issue.

3. Refocus on the socioscientific issue dilemma. Students refocus their attention on the issue and the associated social problems or controversies.

4. Role-playing task. Students assume roles for engaging in the negotiation of SSI. These roles may include parties to the issue debate or creators of media related to the issue.

5. Meta-reflective activity. Students are encouraged to reflect on their overall experiences with the issue and the underlying science. (p. 359)

Eilks’ model clearly offers a method for incorporating SSIs into student learning by offering enriched experiences. The five steps align with the four stages of Kolb’s (1984)
experiential learning cycle, as students are offered a concrete experience with the issue in Steps 1 and 3, focus on the abstract concepts connecting with the issue in Step 2, create their own extensions of the issue in Step 4, and reflect in Step 5.

While Eilk’s model is helpful in designing one type of SSI-based instruction, Sadler (2011) posited the model to be “too prescriptive” to be applied to a variety of educational contexts, and proposed a framework that highlights considerations when designing SSI-based instruction rather than a step-by-step approach. This framework for SSI-based education includes four elements: classroom environment and teacher attributes, which impact the learning experience, and design elements and learner experiences, which make up the learning experience.

Design elements consist of “considerations that practitioners and curriculum authors should incorporate in their efforts to create units of instruction based on SSI,” (Sadler, 2011, p. 361). Essential design elements involve selection of an appropriate SSI and the early incorporation of that SSI into instruction. Also considered essential design elements are scaffolding to develop higher-order thinking skills, such as argumentation and decision-making, as these are not expected to be developed without overt and deliberate practice, and the inclusion of a culminating experience, designed to allow learners to come full circle in the experiential learning cycle by tying concepts and reflections back to the original SSI. Sadler (2011) recommended the use of media to increase student interest in the SSI and to tie the SSI to the students’ world outside of school, as well as the use of technology as an ever-current learning tool due to the rapidly changing nature of SSIs.
Learner experiences pertain to the “kinds of experiences that students should have as they are engaged in SSI learning” (Sadler, 2011, p. 362). While the concrete experience with the issue is a primary focus of the design elements, the learner experiences incorporate the experiential learning cycle’s other three stages, as Sadler stated essential experiences should allow learners to engage in higher-order thinking skills, address the scientific concepts and theories related to the SSI, test ideas by collecting and analyzing data, and negotiate the social dimensions of the issue. Sadler also recommended that learner experiences consider both ethical dimensions and NOS themes related to the SSI, as these aspects enhance student learning, but are not completely necessary in SSI-based instruction.

The similarities between Kolb’s model and the two central aspects of Sadler’s framework suggest that both models can be incorporated into the development of SSI-based instruction. However, Kolb’s cycle focuses strictly on the actions of learning experiences, while Sadler’s framework incorporates classroom environment and teacher attributes as items that impact these actions.

Classroom environment consists of factors that play a role in the successful implementation of SSIs into student learning experiences related to the class’s culture. Essential features include established high expectations and norms for student participation, a collaborative and interactive culture, a demonstration of respect between teachers and students, and a safe environment in which differing perspectives can be expressed. These factors of classroom environment are crucial to the enrichment of student learning experiences because of the controversial nature of SSIs and the level
of collaboration and discussion required in order to develop higher-order thinking skills (Sadler, 2011).

Teacher attributes also impact successful implementation of SSIs into enriched student learning; Sadler (2011) specified four essential teacher attributes necessary when incorporating SSI-based instruction. These require that teachers are familiar with both the science content and social considerations of the SSI and surrounding issues, as they should help students connect the issue with the science surrounding it.

Teachers should also hold a realistic view about limitations of their own and society’s knowledge regarding the SSI, as the evolving nature of SSIs has implied that even the science community does not know everything about the issue. Teachers ought to be willing to accept uncertainties in the classroom, as the controversial nature of SSIs leads students to discuss alternative opinions, resulting in multiple potential acceptable decisions. Discussions involving students do not lead to one right answer, which may put teachers in a knowledge-contributing role, allowing students to develop the discussion as they see fit. Teachers must be comfortable giving up centered control of the discussion’s direction, allowing all member of the class (including the teacher) to be knowledge contributors.

**Factors Influencing Learning Experiences**

While Sadler’s (2011) model exposed the factors to be considered when designing SSI-based instruction, the overall learning experience includes additional factors, as depicted by Dunkin and Biddle’s (1974) model for the study of classroom teaching (Figure 2-3). While several factors, such as teacher attributes and the learning experiences to be had, overlap the two models, Dunkin and Biddle incorporated factors concerning the student and the overall outcomes of the learning process in their
consideration of classroom teaching factors. Adapting a model proposed by Mitzel (1960), Dunkin and Biddle’s model for the theory of classroom teaching grouped thirteen classes of suggested variables into four larger classes, titled Presage, Context, Process, and Product variables.

Presage variables are identified as those that teachers bring to the learning experience through their formative experiences, training experiences, and personal properties (Dunkin & Biddle, 1974). These variables are able to be controlled by teacher educators and administrators through selection and preparation experiences of teacher candidates. Teacher formative experiences “include every experience encountered prior to teacher training, and for older teachers subsequent experiences as well” (Dunkin & Biddle, 1974, p. 39). Although Dunkin and Biddle offered physical attributes as examples of formative experiences, these can also include nonphysical attributes, such as the settings in which teachers were raised or their previous social experiences. Once pursuing a career in education, individuals encounter teacher training experiences, which encompass all training and practice experiences during preservice, inservice, and post-graduate education. The final presage variable, teacher properties, considers how teacher formative and training experiences are expressed by the individual, and encompasses “measurable personality characteristics the teacher takes with her into the teaching situation” (Dunkin & Biddle, 1974, p. 40).

Context variables, which are those that are uncontrolled by the teacher, are depicted as pupil formative experiences and properties, school and community contexts, and classroom contexts. Similar to teachers, students bring formative experiences with them to the classroom, and these can be impacted by aspects such as
home life, socioeconomic status, and physical attributes. Pupil properties, again defined as those measurable personality characteristics which impact a learning experience, are commonly measured when examining impacts of classroom teaching. Context variables also include school and community contexts, which impact the learning experience through the culture and environment of the school and surrounding community, as well as the relationship between the two. Classroom contexts are impacted by the school-community relationship, and can include aspects such as class size, equipment available, and classroom culture.

The presage variables and context variables interact to form process variables – those which concern the observable or measurable behaviors of teachers and students in educational settings (Dunkin & Biddle, 1974). These actions can include those which are intended as well as behaviors which are unintended. The model depicts the interaction of teacher and student behaviors to lead to observable behavioral change because both initial teacher and student behavior, stemming from presage and context variables, as well as reactions to the behaviors of others, lead to behavioral change.

These behavioral changes stemming from classroom interaction are titled product variables. While most product outcomes focus on immediate student growth, long term effects on students, such as employment and post-secondary success, are also products of classroom interaction. Further, these products may be those that are intended and desirable or those that are unintended and undesirable.

**Conceptual Framework**

Just as Kolb’s (1984) experiential learning cycle can be incorporated into Sadler’s (2011) SSI-based instruction framework, the latter framework can be integrated into Dunkin and Biddle’s (1984) model of the theory of classroom teaching to develop a
more holistic concept of SSI-based instruction and its impact on student learning.

Presage variables and teacher classroom behavior encompass Sadler’s teacher attributes, while classroom environment is similar to classroom attributes. The actions of learning experiences in a classroom are accounted for in Dunkin and Biddle’s process variables, but can be more accurately framed for use in SSI-based education through both the stages of Kolb’s (1984) experiential learning cycle and Sadler’s (2011) design elements and learner experiences. Dunkin and Biddle’s model incorporates factors and considerations that stem from the community, which may be especially pertinent to SSI-based education due to the societal controversy surrounding the issues introduced into the classroom experiences. Finally, the purpose of teaching is expressed through Dunkin and Biddle’s model through product variables, which are omitted from Sadler’s framework. Through the combination of the experiential learning cycle (Kolb, 1984), the framework for SSI-based instruction (Sadler, 2011), and the model for the theory of classroom teaching (Dunkin & Biddle, 1974), a holistic model for the evaluation of the SSI-based instruction can be conceptualized (Figure 2.4).

**Presage Variables**

As stated previously, presage variables are those teacher characteristics which may impact learning experiences (Dunkin & Biddle, 1974). Although a relatively under-utilized component of research in SSI-based instruction, presage variables have been the focus of numerous academic integration research endeavors in agricultural education. The blending of SSI-based instruction and agricultural education may benefit from a continued focus on these presage variables.
**Teacher formative experiences**

Sadler's (2011) recommendations regarding teacher attributes that enhance SSI-based instruction imply that teachers’ previous experiences can impact students’ learning. While teachers are recommended to consider their own experiences and limitations regarding SSIs, these features have not yet been the focus of SSI-based education research. Dunkin and Biddle (1974) offer several examples of teacher formative experiences that can impact a teacher’s behavior in the classroom, including socioeconomic status, gender, and ethnicity. Additional aspects of teachers’ experiences, such as their personal views of a specific SSI and their subsequent involvement with the SSI, are theorized to have the potential to impact their teaching (Sadler, 2011). Further, many agriculture teachers are thought to enter the profession due to their personal experiences with the agricultural industry (Shoulders & Myers, 2012), which may result in further teacher biases that must be set aside during instruction.

**Teacher development experiences**

Teacher development experiences have been incorporated into both SSI-based education and agricultural education research, although more as a component of a research design rather than as an independent variable. The studies of Barab, Sadler, Heiselt, Hickey, and Zuiker (2007); Klosterman and Sadler (2011); Lee and Erdogan (2007); Roth and Lee (2004); Yager, et al. (2006); Zeidler, Sadler, Applebaum, and Callahan (2009); Osborne, Erduran, and Simon (2004); and Sadler, Klosterman, and Topcu (2011) displayed the value that researchers have held for the inclusion of teacher training in the design of SSI-based educational research.
Klosterman and Sadler (2011) involved two teachers in the design of a three-week unit focusing on global warming. These teachers then incorporated the SSI-based unit into their environmental science and chemistry classes, both “fully implement[ing] the full unit including both assessments” (p. 1023). The authors recognized the use of only two teachers as a limitation to the study, but justified their decision by stating that this small group allowed enhanced collaboration during the project’s design. While the inclusion of teachers into the design was not explicitly included as an independent variable in the study, the authors implied that this inclusion was a beneficial aspect of the instrument’s development.

Lee and Erdogan (2007) performed a study with seven Korean physics teachers who participated in a four-week professional development program at the University of Iowa. These teachers were chosen for the program based on established criteria including “successful teaching experience, contributions to science education as science teachers, and English proficiency level” (p. 1318). Again, while the purposive use of this group of teachers was not included as an independent variable, the authors discussed the potential benefit that ongoing professional development programs could offer for teachers looking to engage in new, SSI-based teaching approaches.

Roth and Lee (2004) conducted a three-year ethnographic case study of middle school students’ science activities during a community effort to learn more about a local creek and its surrounding problems. During their study, the authors co-taught with seventh-grade teachers in three classes for between two and four months. As has been seen with several other studies, justification for this method of implementation was not
provided, although the study implied that this co-teaching between researcher and teacher was a valuable component of the research design.

Barab, et al. (2007) purposively selected one teacher to deliver learning experiences using a virtual gaming program entitled Quest Atlantis, designed to teach gifted fourth grade students about the multiple facets of water quality and conservation over a ten day unit. The teacher was chosen because she “was an exceptional educator with whom the first author had been involved in another project and who was very comfortable with university educators coming to conduct research in her classroom” (p. 64). Further, this teacher was chosen because the authors viewed her previous experience with Quest Atlantis, combined with her formative experiences regarding research involvement, as a favorable combination to enhance the learning experiences offered by the Quest Atlantis interface.

The study by Yager, et al. (2006) was the result of teacher involvement from its outset, as the idea for the study was developed by two teachers who had participated in the National Science Teacher Association’s Search for Excellence Program and were interested in conducting action research to compare the impact of SSI-based instructional approaches to that of traditional instructional approaches. The teachers “sought help from university science educators in terms of defining [science-technology-society] and in terms of ways of collecting information for the study. It was not primarily an experimental study posed by researchers…” (p. 251). The nature of the study’s origin required that the teachers were involved in the instrument’s design, and their capability for doing so was described in detail by the authors. Teachers’ abilities were established through their established collaborative practices and noncompetitive
relationship, their interest and drive to incorporate innovative teaching methods, their previous involvement in action research projects, their desire for ownership in the project, their previous teaching experience, and their involvement in community organizations and causes.

Zeidler, et al. (2009) conducted a study involving high school Anatomy and Physiology classes that were assigned to treatment and comparison groups. Each of the four classes was taught by the same instructor, who was chosen because of his in-depth experience with the course standards and traditional methods of instruction, as well as his up-to-date knowledge regarding the SSIs used in the study. In order to provide support for the teacher’s use of new SSI-based instructional practices, the researchers deemed it necessary to “maintain continuous and open involvement on daily, weekly, and monthly assessments of the progress of the class, student engagement, class discussion and writing performances, as well as the quality of the activity design” (p. 80). The authors claimed that this constant collaboration maintained teacher confidence when incorporating the innovative teaching strategies.

Osborne, et al. (2004) investigated the effect of an SSI-based unit on eighth grade students’ argumentation skills in London. The study was experimental by design, including an experimental group, through which students learned content in an SSI-based environment, and a comparison group, through which students learned content in a scientific context. Twelve teachers were chosen to participate in the project based on their previous experience and high level of confidence in teaching science, “as the work would involve a degree of risk on their part requiring the use of innovative or unfamiliar pedagogy” (p. 999). Teachers were involved in extensive training for one year, which
consisted of professional development focused on teaching argumentation skills and the development of teaching materials. During this year, the teachers also taught nine argument-based lessons, two focusing on a specific SSI while the rest focused solely on argument in science. Teachers that demonstrated significant progress “in their ability to facilitate and incorporate argumentation into their pedagogical practice” (p. 1000) were selected to repeat the process during the second year, during which student argumentation skills were measured. Implied through this extensive process of teacher involvement and training are the authors' high value in teacher training in order to appropriately incorporate SSI-based instruction into classrooms.

Based on difficulties teachers faced in past SSI-based instruction implementation efforts, Sadler, et al. (2011) “chose to initiate teacher collaborations at the outset of [their study] in order to involve them in the design process with the goal of creating materials geared specifically for their use” (p. 47). As with other studies, this teacher training was not an independent variable that was measured, but was purposefully incorporated into the research design. Because one of the goals of the overall project was to design appropriate SSI-based instructional materials for specific class needs, the two partnering teachers’ needs and classrooms were considered in the design of the instruction. Aspects that factored into the SSI-based instruction included the average level of achievement in both teachers’ classes, the teachers’ status as early-career, the classes taught (chemistry and environmental science), and the needs of the communities (rural town and university-based city). The research team, including the two teachers, met regularly throughout a semester to gain an in-depth understanding of SSI-based instruction and develop the SSI-based curriculum.
Teacher properties

Dunkin and Biddle described teacher properties as those consisting of “measurable personality characteristics the teacher takes with her into the teaching situation” (p. 40). Through these properties, the teacher’s formative and training experiences are brought into the classroom. While studies regarding teacher properties have been rare in SSI-based education research, agricultural education research has considered these properties a focus with regard to teacher incorporation of specific practices for some time. An examination of both areas of research can assist in determining how SSI-based instruction can be best implemented by agriculture teachers.

Teacher perceptions of academic integration in agricultural education.

Since the National Research Council’s 1988 recommendation to integrate academics into agricultural education, teacher perception of science integration has been a prominent area of research in the profession. SSI-based instruction is primarily a method incorporated into science-based classes (Klosterman & Sadler, 2011; Lee & Erdogan, 2007; Zeidler, et al., 2009), and will depend on teacher cooperation and motivation to improve student scientific literacy through innovative teaching approaches in order for SSI-based instruction to be successfully implemented into agriculture classes, as has been seen in science classes already (Zeidler, et al., 2009).

In 2001, Layfield, Minor, and Waldvogel conducted a study designed to determine South Carolina agriculture teachers’ perceptions regarding barriers of science integration. Using a survey design, the authors found that teachers felt prepared to teach integrated biological concepts, yet perceived numerous barriers to
doing so, including the availability of appropriate equipment, lack of funding, and the scarcity of professional development opportunities.

Using the same methods, Balschweid and Thompson (2002) conducted a study to determine Indiana agricultural science and business teachers’ perceptions regarding science integration. They reported that respondents agreed with statements supporting science integration into agricultural education. However, these teachers reported the same top three barriers as teachers in the Layfield, et al. (2001) study. Further, 36.6% of respondents “indicated they had less time to prepare for classes and/or less personal time during their teaching day as a result of integrating or planning to integrate science” (p. 7).

Warnick and Thompson (2007) distributed a similar perceptions survey to agriculture teachers in one state. Again, a majority of the respondents perceived the lack of appropriate equipment as a barrier to science integration. Of note in this study’s results is that 30% of the respondents identified their own lack of science competence as a barrier to science integration. Finally, while a majority of the respondents agreed that collaboration between the school science department and agriculture department would benefit science students, fewer than one-half reported participating in such collaboration.

Myers and Washburn (2008) conducted a study assessing the perceptions toward science integration of Florida agriculture teachers, and found that teachers felt students learned more science and agriculture content through integration of the subjects, and that collaboration increased their ability to teach students how to solve problems. Over half of the respondents felt that science integration required increased
preparation, with over two-thirds reporting insufficient planning time as a barrier to science integration.

**Teacher attitudes regarding SSI-based instruction.** Few studies have examined teachers’ perceptions regarding the incorporation of SSIs into instruction. However, this lack of research could be caused by the large number of studies that included teachers throughout the design process, implying that teachers are proponents of SSI-based instruction before they participate in SSI-based instruction research (Barab, et al., 2007; Klosterman & Sadler, 2011; Lee & Erdogan, 2007; Osborne, et al., 2004; Roth & Lee, 2004; Sadler, et al., 2011; Yager, et al., 2006; Zeidler, et al., 2009). Contrary to this implication, the following studies began to unearth teacher perceptions of SSI-based instruction.

Sadler, Amirshokoohi, Kazempour, and Allspaw, (2006) conducted a qualitative study using interviews from 22 middle and high school science teachers to gather information regarding teacher perspectives about the use of SSI in science education, specifically focusing on the ethical aspects of instruction. The interviews resulted in the unearthing of five profiles regarding perceptions of SSI and ethics: (a) participants view SSI as important aspects of science education, suggest that ethics are involved in SSI curricula, and present SSI in their classes; (b) participants view SSI as important aspects of science education, but the current realities of schooling impede the enactment of SSI-based curricula; (c) participants hold ambivalent attitudes toward SSI in science curricula and do not feel their professional responsibilities include facilitating the exploration of ethics; (d) participants reject the idea that science and ethics are interrelated and is opposed to science classroom treatments of ethics; and (e)
participants suggest that values should be important aspects of all education (p. 261-362). While middle school teachers gave responses that coincided with Profiles A and B, high school teachers gave responses that coincided with Profiles A, B, and C. Only one of the 22 teachers offered responses coinciding with Profile D, indicating that the vast majority of the respondents perceived the benefits of incorporating SSI and ethics into science curricula, even if they were unsure of how to put that perception into action.

Bryce and Gray (2004) conducted a qualitative study with a group of 10 Scottish teachers who attended a professional development session and were in the process of teaching their first class of Advanced Higher Biology. The professional development was designed to update teachers on “new science,” including content which focused on biotechnology and genetics, as well as “a raised awareness of the social, ethical, and moral issues arising from their use” (p. 718). Teachers were interviewed after three months of teaching the new Advanced Higher Biology course to explore their reactions to controversial discussions and new aspects of science associated with the SSIs integrated into the class. Interview themes revealed that teachers found controversy in science to be “part-and-parcel of how science and technology is advancing and should figure…in all courses” (p. 724). Teachers also felt that contextualization and human testimony aided in presenting biotechnology content to students in a meaningful way, provided that it was presented from both sides and allowed the teacher to remain neutral on the topic. Teachers stated that certain topics, such as animal experimentation, quickly led to heated emotional discussion. They indicated that they wanted more instruction on the pedagogy associated with classroom discussion of ethical issues, including the purpose of the discussion, time allowed, and the extent of
their own participation. Connected to this desire for increased instruction in discussion pedagogy was teachers’ expressions of a lack of confidence in handling topics that raised student emotions. Lack of confidence in handling these topics stemmed from “a lack of knowledge of the science concerned…unfamiliarity with specific related issues…being unaccustomed to handling awkward personal issues in the classroom…[or] being unsure of to whom/what interested pupils might be referred in the case of particularly challenging subject matter” (p. 727).

**Teacher opinions regarding specific SSIs.** While no studies were found to assess teachers’ opinions regarding specific SSIs, Sadler (2011) recommended that teachers accept their roles as inquirers and give up some authoritarian control during SSI-based instruction. Teachers’ opinions of their roles during SSI-based instruction was the focus of one study, which serves as a starting point in a line of research that should be continued, as teachers are responsible for allowing differing perspectives to be shared openly within the classroom (Sadler, 2011).

The study conducted by Sadler, et al. (2006) explored the perceptions of 22 middle and high school teachers regarding SSI-based instruction and found that all participants “agreed that teachers should not attempt to impose their own values on students, and that the primary goal of dealing with ethics in science was to promote critical thinking and student exploration of their own values” (p. 370). A majority of the teachers stressed their perceived responsibility to present alternative viewpoints of controversial topics, and either felt it was necessary to completely avoid sharing their personal views, or would only do so following persistent student questioning. Other teachers felt that it was their responsibility to share their personal beliefs in order to act
as role models to students, assuming their values “represented mainstream, American values”, which was thought to be “less problematic” (p. 371). One teacher felt that while teachers should not explicitly share their values, but that their beliefs and values emerge through their classroom behavior.

Context Variables

Context variables consist of student and classroom aspects to which the teacher must adjust (Dunkin & Biddle, 1974). As with presage variables, these have rarely been the focus of SSI-based education research, yet have been incorporated into research designs in most studies.

Pupil formative experiences

Students’ experiences before entering the classroom have widely been ignored in both SSI-based and agricultural education research. However, the social focus of SSI-based instruction implies that students have experiences outside of the classroom that impact their learning through SSI contexts (Sadler, 2011), causing need for research in the impacts of pupil formative experiences on SSI-based instruction in agricultural education.

**Students’ exposure to SSI.** In 2003, Dhingra conducted a study designed to explore the impact of different television programs on students’ understanding of the NOS. While the study lacked some generalizability due to the author’s use of single-sex high schools, this sample choice in itself holds meaningful implications for SSI-based instruction research. During the process of conducting research, Dhingra could only gain access to these classes, as other administrators felt that “television-mediated learning was not a serious enough subject to merit the time that would be lost from science class” (p. 238). After watching four television programs, each of which was
placed into a different program category (News, Documentary, Fictional Programming, and Magazine Format), Dhingra utilized interviews, an open-ended questionnaire, small group discussions, and free writing responses to gain a qualitative understanding of how these programs impacted students’ views of the NOS. Emerging from the data were several findings: (a) students questioned the ethics and validity of science of programs in the news category because of the revolutionary nature of the science presented and because of the critical voice used during news reports, (b) students viewed documentary and magazine format programs as final form science rather than tentative, (c) students felt as though certain fictional science practitioners were role models and helped students self-identify their own interests in scientific careers, and (d) students had differing views on the degree of connectedness between school science and television science. Dhingra recommended that further research be conducted in order to combine the efforts of free-choice education and formal education to increase scientific literacy.

**Pupil properties**

While many studies have discussed the demographic characteristics of students, few have examined how SSI-based instruction impacts students of varying properties differently. Those that have incorporated pupil properties into research questions have focused on students’ differing academic levels.

Dori and Herscovitz (1999) examined high school Israeli students’ question-posing capabilities before and after experiencing a unit focusing on the quality of air. Students were divided into three academic levels based on both school placement and pretest scores. High achieving students were science majors and engaged in the Quality of Air Around Us module for extra credit. Medium achieving students, who were of average
capability, and low achieving students, who possessed some learning difficulties, engaged in the Quality of Air Around Us unit through their Science and Technology for All course. During the pretest and posttest, students read case studies and posed questions to the cases which were then analyzed according to the number of pretest and posttest questions posed by each student, the orientation of each question, and the complexity each question. While each academic level displayed improvement in number of questions, question orientation variability, and question complexity, results indicated that the differences varied among academic level, with high achieving students improving the most as a result of the treatment. Further, students were exposed to one topic more thoroughly than other topics, allowing for their level of topic expertise to be compared with their questioning capabilities: “high academic level students maintained the same level of knowledge in their expert topic as in the other topics. The knowledge level of medium and low academic level students “declined significantly and proportionately in other topics compared to the expert topic” (p. 426).

Using pretests, posttests, teacher interviews, and student portfolios, Dori, Tal, and Tsaushu (2003) examined the differences in higher order thinking skills gained by students of differing levels of achievement as a result of experiences with a SSI module based on biotechnology. The authors operationalized higher order thinking skills as cognitive activities that are beyond the level of understanding according to Bloom’s traditional taxonomy (Bloom, 1956). Thus, recall knowledge and understanding of information are classified as lower order thinking skills. Analyzing information and data presented in case studies, posing questions, providing scientifically grounded arguments, expressing opinions, making decisions, and system thinking would be classified here as higher order thinking skills. (p. 771)

Students were categorized based on academic level as a result of pretest scores and teachers’ recommendations. Unique to this study was the assessment instruments.
Students were presented with eight assignments, four being considered low level and four being considered high level with regard to the thinking skills required to respond to the assignment. Students then chose three of the four low level and three of the four high level assignments to complete a total of six assignments. Student responses were analyzed to determine students' abilities to pose questions, display argumentation skills, and think in systems. Results indicated that students in all three academic levels (low, intermediate, and high) displayed statistically significant improvement in higher order thinking skills between pre and posttests. While there was no significant difference between the gains of high and intermediate students, the gains of these two groups combined were significantly different from low achieving students. With regard to knowledge and understanding, low achieving students actually displayed higher posttest scores than high achieving students, while high achieving students displayed higher posttest scores in higher order thinking skills. These results led the authors to posit that “teaching biotechnology in an STS approach with discussions about scientific and social issues, contributes towards narrowing the gap in the knowledge and understanding category to a higher extent than in the higher order thinking skills category” (p. 778).

Dori, et al. also examined the student assignment choices and found that high achieving students preferred assignments that required question posing while low achieving students preferred those that required system thinking in addition to question posing.

**Classroom contexts.**

SSI-based education research designs have included a variety of classroom grade levels and subjects. While these have not been the focus of research questions, they do provide insight into the range of ages that have been exposed to SSI-based instruction,
as well as the content areas through which SSI-based instruction has been implemented thus far.

**Student grade level/age.** SSI-based instructional research has been incorporated into classes in many different countries and at many different grade levels. Studies have focused on implementation into upper elementary classes (Barab, et al., 2007), middle school classes (Osborne, et al., 2004; Roth & Lee, 2004; Yager, et al., 2006), high school students (Dori & Herscovitz, 1999; Dori, Tal, & Tausch, 2003; Jimenez-Aleixandre, Rodriguez, & Duschl, 2000; Klosterman & Sadler, 2011; Kolsto, 2001; Sadler, 2004; Tal & Hochberg, 2003; Zeidler, et al., 2009; Zohar & Nemet, 2002), and college students (Eastwood, Schlegel, & Cook, 2011; Sadler, Chambers, & Zeidler, 2004; Wong, Hodson, Kwan, & Yung, 2008).

**Class subject.** While SSI-based instruction has been incorporated into a wide variety of grade levels, the subjects into which SSIs are included consist of a broad range of science areas. None of the previously conducted SSI-based studies has been outside the realm of science-based classes. The classes through which SSI-based instruction has been taught are Chemistry (Klosterman & Sadler, 2011; Sadler, et al., 2011), Environmental Science (Klosterman & Sadler, 2011; Sadler, et al., 2011), Physics (Lee & Erdogan, 2007), Anatomy and Physiology (Zeidler, et al., 2009), and general science (Dori, et al., 2003; Drache, 1996; Kolsto, 2001).

**Process Variables**

Dunkin and Biddle (1974) stated that the actions occurring in a classroom are the result of teacher and pupil behaviors and interactions, a position that is supported by Sadler’s (2011) SSI-based instruction framework. The studies investigated below
therefore are organized according to their fit into Sadler’s four components of SSI-based instruction.

**Design elements relating to SSI-based instruction**

Sadler (2011) claimed that a compelling social issue is the foremost priority when designing SSI-based instruction. Studies utilized varying types of SSIs when designing instruction. Issues in genetics, environmental sciences, animal welfare, and health were frequently utilized, with some authors justifying their use of a particular SSI and others assuming that the issue chosen was deemed an appropriate SSI.

**Genetics.** Jimenez-Aleixandre, et al. (2000) studied one class of ninth graders in Spain during six one-hour genetics sessions. While the first four sessions did not contain any SSI-based implementation, the final two sessions were modified by the researchers and focused on an SSI. The specific SSI explored the economic ramifications of domestic chicken coloring being different than wild chicken coloring, and potential genetic solutions to produce wild-looking domestic chickens. The authors defended their use of this fictitious SSI by stating that it mirrored a real local problem of fish farmers producing unmarketable fish due to the color differences between wild and farm-raised fish.

Dori, et al. (2003) designed a module entitled Biotechnology, Environment, and Related Issues, which was developed in Hebrew to teach tenth-twelfth grade Israeli non-science majors about scientific knowledge related to biotechnology and genetic engineering through several case studies. The module included four separate biotechnology-related SSIs: (a) increasing agricultural productivity through genetic engineering; (b) connecting the processes of making wine and bread to process of modern biotechnology, specifically insulin production; (c) the human genome project
and tissue culture; and (d) gene therapy, changing human genetic traits, and cloning. As is noted in the four units, students learn about the history of traditional biotechnology and then connect that historical perspective with recent advancements in biotechnology, finishing the module with a focus on the ethics of more controversial SSIs.

Tal, Kali, Magid, and Madhok (2011) utilized the Web-based Inquiry Science Environment (WISE) to provide eighth-tenth grade students in Tel Aviv with an internet-based module focusing on genetics, entitled Simple Inheritance. Through the module, students were first exposed to the SSI through a story of a boy suffering from cystic fibrosis (CF). They followed the boy’s family history to determine how the disease was inherited, which then was connected to the inheritance of other traits and simple genetic mechanisms. The module utilized online interaction with a CF patient and a field trip to a hospital to increase the real-world context of the SSI.

Sadler and Zeidler (2004) conducted a qualitative study to assess how college students perceive genetic engineering issues with regard to morality. The participants were asked to read handouts that focused on gene therapy’s use to combat Severe Combined Immune Deficiency and cloning as a means to overcome infertility, and were asked questions regarding these SSIs and other related SSIs upon their completion of each of the readings. The authors justified their use of a genetics-based SSI by considering its recent relevance in societal issues, which was thought to increase participant interest.

Zohar and Nemet’s (2002) study examined the impact of explicit argumentation instruction during ninth grade Israeli students’ exploration of dilemmas in genetics. This unit, titled the Genetic Revolution – Discussions of Moral Dilemmas, was developed
through the Thinking in Science Classrooms project, “in which learning activities
designed to foster higher-order thinking skills and scientific argumentation are
integrated into the regular junior high school science curriculum” (p. 40). Genetics topics
of the 12-hour unit included genetic counseling, traits and inheritance, gene therapy,
and cloning. Justification for use of this topic was provided; the authors felt that
genetics-based SSIs would create “an authentic environment for argumentation that
students would find interesting and motivating” (p. 40).

**Health.** Through the use of a WISE module, Tal and Hochberg (2003) examined
reasoning and problem solving abilities of ninth-grade Israeli students. After a pilot study
in which an SSI focusing on deformed frogs was used, the authors determined that a
more socially relevant SSI would be beneficial to the study. The Malaria Project was
thus chosen as the SSI for the study, through which students “learn about the biology of
the disease, where it is prevalent, and how it spreads, and they compare three different
strategies for controlling the spread of malaria” (p. 4). The authors chose to engage
students in the malaria module because of malaria’s history in Israel and its recent
return to the spotlight due to immigrants bringing malaria parasites into the country
within the last ten years. According to the authors, “these facts make the topic not only
important in general, but also locally relevant” (p. 4).

Eastwood, et al. (2011) examined the impact of SSI-based instruction on college
students through a unique “four-year university program designed to integrate biology
with social aspects of the human, scaffolding students to develop their reasoning related
to complex issues and advocate for their own committed positions” (p. 89). While the
program contained requirements similar to those of traditional biology majors, it also
included courses in the areas of human environment and ecology, human origins and survival, human health and disease, and human reproduction and sexuality, along with an annual core course designed to focus on the SSIs of these areas. The annual course “connected primary biological concepts with related social and ethical issues and explicitly addressed epistemological concepts in biology including uncertainty, tentativeness, and the centrality of evidence to knowledge in biology” (p. 94). In their study, the authors examined the decision making practices of sophomore students who were enrolled in an interdisciplinary course that focused on death and dying, infectious disease, and HIV and AIDS.

Kolsto (2001) examined the decision making practices of tenth grade Norwegian students after they experienced two lessons that focused on a local debate about the role of power transmission lines in an increase in childhood leukemia. The author justified the use of this SSI-based on its coverage in Norwegian newspapers and its links to science content.

Wong, et al. (2008) conducted a study in Hong Kong that sought to explore how SSI-based education impacted student teachers’ understanding of the NOS. The SSI utilized was the severe acute respiratory syndrome (SARS) epidemic as the context for teaching student teachers scientific inquiry and aspects of the NOS. Authors deemed this an appropriate SSI because it was a meaningful and familiar issue in Hong Kong, and was publicized widely throughout the scientific processes leading to its control.

**Animal welfare.** Osborne, Erduran, and Simon (2004) examined the effect of a contextually-based unit, with the first and final lessons focusing on whether zoos should be permitted, on eighth-grade students’ argumentation skills. The remaining units
focused on argumentation in the context of science; however, students’ argumentation skills were assessed using verbal and written evidence focusing on the pros and cons of zoos and whether or not the students felt that a new zoo should be built.

**Environmental issues.** In an Israeli class designed to teach scientific literacy through SSI entitled Science and Technology for All, Dori and Herscovitz (1999) incorporated a Quality of Air Around Us, in which five independent topics related to air quality were introduced. Through lessons about nitrogen oxides, sulfur oxides and particles, carbon oxides and the greenhouse effect, ozone layer depletion, and odor as an inconvenience versus a pollution, students learned about “basic concepts in ecology, higher-order cognitive skills, critical thinking, asking questions, judging values, solving problems, and using creativity” (p. 416).

A study by Barab, et al. (2007) study using Quest Atlantis immersed fourth grade gifted students in the multiple facets of environmental issues through a storyline focusing on the problems of “Tiaga Park,” a fictitious location faced with a decline in fish numbers severe enough to warrant the local fishing company, the source of much of the park’s revenue, to consider relocation. The SSI was further developed through the students’ consideration of the concerns, needs, and actions of an indigenous population, a logging company, and the fishing company. Student objectives during the lesson included learning the concepts of erosion, eutrophication, water quality, and system dynamics, as well as developing a “richer commitment to environmental awareness” (p. 62).

Klosterman and Sadler (2011) designed a three-week unit focusing on issues surrounding global warming. The seven learning exercises exposed students to
scientific concepts such as “atmospheric composition, the measurement and absorption of radiation by CO₂ and other gases, the process of combustion, and the explanations for and causes of climate change” (p. 2013) through exercises including reactions to news articles, evaluation of the perspectives of fictitious organizations, laboratory exercises, and discussion.

Roth and Lee (2004) conducted an ethnographic study in a community in which they both live. Through a collaborative effort of community and academic participation, students learned about problems associated with a local watershed’s ability to provide consistent water to the community. Contributing to this SSI were climate, urban development, citizen practices, erosion, and agricultural runoff, each of which are components of the overall student learning experiences.

While the study by Eastwood, et al. (2011) examined sophomore decision making practices while enrolled in a health-related interdisciplinary course as part of an SSI-based four-year university program, the study also included program students at the senior level who were enrolled in the appropriate level interdisciplinary course. The senior level course focused on global warming, service learning through the local Parks and Recreation Department’s state river water quality program, and advocacy of environmental conservation.

Sadler, et al. (2011) developed a unit of SSI-based instruction that focused on global climate change. The goals of the unit were to allow students to “develop an understanding of what global climate change is and why various parties think that this is a significant issue…develop understandings of scientific principles and concepts related to global climate change…engage in scientific practices…develop understandings
related to why global climate change is controversial...develop skills for finding and analyzing web-based resources related to SSI...formulate a personal position on global climate change that is informed by scientific principles and concepts...[and] improve their socioscientific reasoning practices in contexts beyond the scope of global climate change” (p. 51-52). Through a nine-lesson unit, students learned about factors of global climate change that culminated in the creation of a product that promoted a specific action related to climate change.

**Learner experiences relating to SSI-based instruction**

Sadler’s (2011) SSI-based education framework includes learner experiences as a main component, and these experiences are thought to provide a vehicle for learning (Dewey, 1938). As with presage and context variables, these learner experiences were rarely the independent variable in studies, except that the SSI-based education provided a learning experience in a specific type of context. However, several studies discussed their use of specific types of learning experiences, such as the incorporation of technology and use of experiential learning strategies.

**Incorporation of technology.** Barab, et al. (2007) engaged students in decision making regarding water quality through Quest Atlantis, a multi-user virtual environment through which students are immersed in a simulation of aquatic habitats. Quest Atlantis incorporates multiple users and game-based role-playing pedagogies into a 3-D virtual environment into an online educational module through which students move using avatars. The online environment is introduced and upheld through a storyline pertaining to a fictitious park’s problem with declining fish numbers. Students then engage in “quests”, participating in “real-world and simulated, socially and academically
meaningful activities, such as environmental studies, researching other cultures, interviewing community members, and developing action plans” (p. 62).

Tal, et al. (2011) developed a module focusing on genetic inheritance through the Web-based Inquiry Science Environment (WISE), which “was designed to enhance student learning, while taking advantage of the innovations that the Internet can bring into the teaching and learning of science” (p. 13). The WISE library includes dozens of SSI-based modules that have been designed by researcher and teacher teams for use in varying grade levels.

Tal and Hochberg (2003) also utilized the WISE project during a study of the impact of a malaria-focused SSI on students' higher order thinking skills. The authors chose this learning environment because of its low cost, as well as its ability to allow students to “respond to contemporary scientific controversies through designing, debating, and critiquing solutions” (p. 4).

**Constructivist activities/experiential learning**

Yager, et al. (2006) measured the constructivist teaching practices utilized in a SSI-based science class and a traditional science class through the use of Burry-Stock’s (1995) ESTEEM instrument. This instrument measured “18 observable features that collectively define constructivist teaching approaches” (p. 252). The results indicated that the teacher incorporating SSI-based instruction engaged in more constructivist teaching practices.

To enhance the genetics-situated WISE module utilized in their study, Tal, et al. (2011) incorporated online interaction with a patient and a field trip to a hospital in the unit, exposing groups of students to each in order to determine whether the two enhancements yielded different results with respect to students’ perceptions of the
module’s relevance. Analysis of open-ended responses indicated that students experiencing the online interaction were able to improve their learning through the ability to ask questions and were able to gain a better understanding of patient challenges, while those that experienced the field trip noted a connection between the field trip and online module, developed a greater sense of meaning related to their learning, and felt an increased sense of relevance to the module, causing the authors to posit that “the field trip addition was more productive than the online interaction addition in enhancing student interest and self-viewed learning” (p. 30). Students exposed to the online interaction focused mainly on affective aspects in their responses, while those who visited the hospital focused on deeper learning and understanding in addition to affective aspects of the visit. While no significant differences were found between the two groups with regard to knowledge gains, students experiencing the online interaction offered more genetics-based justifications in responses, while field trip students offered more justifications related to a broader social-technological realm.

Hogan (2002) conducted a qualitative study that examined in-class and independent study high school students’ experiences during a service learning project that focused on the development of a watershed management plan. The in-class group of students experienced much of their learning in a classroom setting; the service learning portion of the class consisted of conducting a study in the watershed area. The independent study group of students conducted most of their service-learning at the partnering environmental agency, participating in the daily activities of the agency. Results of interviews found that the groups viewed environmental practitioners differently – the classroom-based group viewed the environmental practitioner profile as
one focused on knowledge of environmental concepts, while the independent-study group described the environmental practitioner profile as one that is more community-oriented, less knowledge-based, and more connected to the people associated with the environmental issue. Hogan concluded that both of these profiles are accurate, yet represent one dimension of a truly multi-dimensional profile. Likewise, the tasks each group participated in were different, yet limiting, as neither group moved beyond a certain set of entry-level activities typical of the setting. Results of this study led Hogan to recommend that the learning culture of the classroom and the doing culture of the service learning be blended in order to increase the success of experiential learning programs.

Although not a specific objective of the study, Lee and Erdogan (2007) stated that the seven Korean physics teachers incorporating a three-week SSI-based instructional unit “experienced difficulties…such as lack of materials for [science-technology-society] teaching, getting away from textbooks, and resistance from students and parents who wanted to learn how to get good scores on tests” (p. 1325), and recommend partnerships with professional development opportunities in order to help teachers gain more confidence in less traditional teaching approaches, such as SSI-based instruction.

**Product Variables**

Product variables include those measurable outcomes produced through learner experiences (Dunkin & Biddle, 1974). The short history of SSI-based education research has led the vast majority of these studies to focus on immediate pupil growth in an effort to legitimize the use of SSI-based instruction in science classes. Again
because of its short history, the long term effects of SSI-based education have yet to be examined.

**Student content knowledge gains**

Barab, et al. (2007) measured gifted fourth graders’ content achievement through both proximal and distal pre- and post-intervention measures upon completion of a 10-day interactive online module focusing on water quality. Proximal-level measures consisted of two open-ended performance items, and were “aligned directly to the specific concepts and skills the… curriculum was designed to address” (p. 65). These items were designed to assess students’ abilities to engage in socioscientific reasoning and understanding of science content knowledge. Distal-level measures were included to assess students’ achievement on similar items, such as those on high-stakes standardized tests. The 18 distal-level items consisted of those released from state science achievement tests, and measured students’ understanding of the underlying standards targeted in the Quest Atlantis module. Students exhibited a statistically significant improvement on the proximal measure, providing evidence that students could transfer their content mastery to traditional classroom tests. While distal measures did not reveal a statistically significant increase in student scores, the authors did note a mean increase in scores, and attributed the lack of significance to a potential ceiling effect.

Klosterman and Sadler (2011) also incorporated both proximal and distal level measures into their study of the impact of a three-week global warming unit on eleventh- and twelfth-grade students’ science content knowledge gains. As in the study by Barab, et al. (2007), the authors developed a distal-level measure assessing specific science standards from a pool of publicly released standardized test items. The
proximal-level measure contained five open-ended questions regarding the specific
curriculum of focus in the global warming instrument. Proximal-level response analysis
indicated a statistically significant difference between pre- and post-assessments on
three of the five questions; the final two questions were not analyzed due to the low
frequencies in each scoring level. Contrary to the results in the 2007 study, Klosterman
and Sadler (2011) found a statistically significant gain with a medium level effect size in
students’ distal-level scores.

In the study by Yager, et al. (2006), which compared middle school students’
academic gains between classes taught through an SSI-based approach and through a
traditional approach, ten weekly quizzes were utilized as a pre- post-test to measure
middle school students’ differences in concept mastery over the course of a semester.
General science achievement was measured through the use of a common science
semester exam, which was again administered as both a pre- and post-test to each
group. Because the authors classified their study as action research, no attempt was
made to validate the instruments or measure the reliability of their scores. Statistically
significant gains were found for students in both groups with both measures. However,
the gains between the two groups were not statistically significant, implying that the
students taught through the SSI-based approach mastered science concepts at a level
equal to that of students learning through traditional methods.

Dori, et al. (2003) examined the knowledge and understanding gains of students in
differing academic levels. While both high and low achieving students improved
knowledge and understanding of biotechnological concepts between pre and posttests,
the low achieving students achieved higher posttest scores than the high achieving
students, leading the authors to posit that SSI-based education may narrow the gap in knowledge and understanding between high and low achieving students.

Tal, et al. (2011) examined Israeli student scientific and genetics knowledge after exposure to the two-week WISE Simple Inheritance module. The science-knowledge integration test combined an original WISE knowledge-integration assessment with a revised version of the test that focused specifically on students’ integrated understandings of the principles of simple inheritance, and lastly, contained a complex question related to how large family exterminations during the Holocaust has influenced simple inheritance, as this situation is relevant to Israeli families. Students were given the test after they were exposed to the module and one of two “enhancements,” which were online interaction with a cystic fibrosis patient and a field trip to a hospital. The authors examined student responses to find evidence of differences in knowledge acquisition between the two groups, and found no significant differences. Because no pretest was administered, the authors could not determine the impact of the overall module on student knowledge acquisition.

Zohar and Nemet (2002) conducted a study designed to explore the effects of a genetics-based SSI unit on ninth grade Israeli students’ biological knowledge. Through the use of experimental and comparison groups, the authors compared biological knowledge gains between the two groups as evidenced by pretest and posttest questionnaires. While the experimental group learned about advanced genetics concepts through the Genetic Revolution unit, those in the comparison group learned the same genetics concepts through a booklet that presented information in a traditional textbook approach. The pretest and posttest consisted of an item designed to “[address]
the extent to which students consider biological knowledge while thinking about the dilemma” (p. 43) and a 20-item multiple choice genetics knowledge test. With regard to consideration of biological knowledge, the authors found that students in the comparison group did not consider biological knowledge when considering the dilemma as frequently as those in the experimental group. This trend was continued with respect to the use of false considerations, as those were found more frequently in the comparison group responses. Alternatively, students in the experimental group correctly considered specific biological knowledge more frequently than those in the comparison group. With regard to biological knowledge gains, results indicated that students experiencing the SSI-based Genetic Revolution unit scored significantly higher than those in the comparison group.

Sadler, et al. (2011) sought to determine the impact of SSI-based instruction on student scientific content knowledge in two high school classes of average-achieving students. The authors posed problems associated with assessments directly aligned with interventions, which are not ideal for use as summative assessments due to their lack of assessment of knowledge transfer, and those that are broader in scope, which are insensitive to small changes resulting from a short-term intervention. To address these issues with types of assessments, this study utilized two different assessments based on their distance from the intervention in order to assess the unit’s impact on students’ scientific content knowledge. Proximal data were collected through the use of a test with items that related directly to the unit, while distal data were collected through the use of items from state and national exams. The proximal assessment included five open-ended questions relating to climate change, which was the SSI focus, and was
analyzed using the constant comparative method. The distal test measured student knowledge in climate and temperature, greenhouse effects and climate change, chemical principles and processes, and graphical creation and analysis. Comparing results for pre and posttests, the authors found that there was a significant increase between the pretest and posttest responses for the first three items of the proximal assessment, indicating that the SSI-based instruction significantly improved students’ proximal responses. Distal measures resulted in a significant increase in students’ correct responses from the pretest to the posttest, with a medium effect size, implying that the SSI-based instructional unit not only helped students learn scientific content in the SSI context, but also transfer the content to other scientific contexts.

**Views of the NOS**

Gaining an understanding of the NOS (NOS) has been a stated educational goal connected with scientific literacy for over a century (Lederman, 2006). Driver, Leach, Millar, and Scott (1996) argued that an understanding of NOS is crucial for individuals to be able to understand science and technology in everyday life, make informed decisions on socioscientific issues, appreciate the value of science in culture, understand the moral norms of the scientific community and society, and learn science as a subject. While these supporting statements are generally agreed upon, definitions of NOS vary greatly among research circles. In education, however, consensus regarding the components of NOS pertinent to the K-12 setting has been better established (Lederman, 2006). Lederman (2006) stated that NOS is a term generally used to refer to “the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development” (p. 833). While he noted that
some authors include or remove certain aspects of NOS, the following characteristics are generally considered to be pertinent to an understanding of NOS at the K-12 level:

Scientific knowledge: (a) is tentative (subject to change); (b) is empirically based (based on and/or derived from observations of the natural world); (c) is subjective (involves personal background, biases, and/or is theory-laden); (d) necessarily involves human inference, imagination, and creativity (involves the invention of explanations); and (e) is socially and culturally embedded (Lederman, 2006, p. 833).

Numerous studies have examined how these aspects and others of NOS are grasped by students engaging in SSI-based education.

Zeidler, et al. (2009) constructed their study around the differences in reflective judgment, a component of NOS, between high school students experiencing NOS content through SSI-based instruction and through textbook driven instruction. Using both qualitative and quantitative methods, the authors found significant differences between the treatment and comparison groups’ reflective judgment development.

In Hong Kong, Wong, et al. (2008) explored the impact of SSI-based instruction on student teachers’ views of the NOS through the use of a unit focusing on the recent SARS epidemic. Through interviews with key scientists involved in SARS research during the epidemic, the authors built a multimedia teaching package that focused on the NOS features present in the SSI. The authors examined the impact of the SSI-based instruction on student teachers’ views of the NOS through the use of a modified version of the Views of NOS Questionnaire (VNOS-C) (Lederman, et al., 2002) before and after the SSI-based unit, and semi-structured interviews with those participants who demonstrated improvement in views of NOS between the pre- and posttests. Results of
the questionnaire indicated that over 20% of the student teachers improved their understanding of eight aspects of NOS, including: “science has inherent limitations, scientific knowledge is tentative, peer review as an important process in the acceptance/validation of scientific ideas, science influences political decisions, science is affected by political decisions, science influences social and cultural practices, science is affected by social and cultural values, and science and technology impact each other” (p. 1425). Interviews revealed that the unit’s immediacy, relevance to their lives, familiarity, transfer of abstract concepts to tangible pieces, links to personal experiences of science history, and focus on affective aspects of the SSI were factors that “played a significant role in promoting understanding of NOS” (p. 1431).

In 2009, Callahan examined the impact of a semester-long SSI-based curriculum on ninth and tenth grade Biology I students’ views of NOS. The researched used both qualitative data from interviews and quantitative data from pretests and posttests using the Views on Science and Education questionnaire (VOSE) (Chen, 2006). Revising the VOSE based on pilot tests, Callahan’s assessment asked questions regarding the tentativeness of scientific knowledge, nature of scientific knowledge, nature and comparison of theories and laws, and the use of imagination in science. Chen (2006) recommended that scoring methods represent the goals of the research, as no view is necessarily incorrect. Callahan’s scoring was based on “agreement with contemporary views of the NOS, with higher scores reflecting more contemporary views of NOS, and lower scores reflecting more naïve views of the NOS” (p. 65). Results from the VOSE did not indicate a statistically significant difference in pretest and posttest scores in any of the areas of NOS. Further, interviews found that “students held a range of NOS
views, and that these views did not change greatly over the course of the study” (p. 105). Callahan speculated that these findings could have been caused by a lack of differentiation between naïve and more sophisticated views of NOS on the VOSE or from respondent fatigue occurring as a result of completing the questionnaire both before and after the intervention.

Using a three-phase design, Zeidler, et al. (2002) examined how high school and preservice elementary teachers’ views of NOS were reflected in their reactions to SSIs when confronted with information that challenged their initial beliefs. The participants initially completed a questionnaire that assessed their views of the following four tenants of NOS, each thought to be most closely related to the SSI being introduced: (a) the tentativeness of scientific claims and why those claims may change; (b) the role of empirical evidence in the activity of science, (c) the role of theoretical commitments, social and cultural factors in generating scientific knowledge; and (d) the extent to which human creativity, imagination, and sociocultural-embedded factors influence formulation of scientific knowledge (p. 347). After experiencing the SSI-based instruction, participants were interviewed in pairs that were arranged according to their levels of conviction regarding certain views of NOS. Qualitative data analysis revealed that while “only a few discernible instances of a clear relationship” (p. 359) between views of NOS and patterns of decision-making on a SSI were found, social and cultural influences guided students’ data evaluation when considering alternative perspectives of the SSI.

In response to limited success in improving student views of NOS through different approaches, Khishfe and Lederman (2006) conducted a study to “investigate the effectiveness of two explicit instructional approaches in enhancing more informed
NOS understandings among students” (p. 398). The integrated instructional approach taught concepts of NOS through a connection with science and global warming, while the nonintegrated instructional approach taught separate lessons on the two topics. NOS aspects included in the lessons were that scientific knowledge is tentative, derived from observations of the natural world, produced from human imagination and creativity, distinguishes between observations and inferences, and is subjective to individual and societal experiences. A questionnaire was used to assess students’ level of sophistication regarding these NOS aspects before and after the six-week intervention, and student responses were categorized into three groups, titled “naïve”, “transitional”, and “informed”. Both the integrated approach and the nonintegrated approach resulted in an increase in student level of sophistication in their views of each of the NOS aspects. However, the integrated group resulted in a slightly greater increase in number of informed responses, while the nonintegrated group resulted in a greater increase in number of transitional responses. This slight difference between the two groups was not warranted to be large enough to make recommendations between the two approaches; rather, the authors recommended that an explicit approach to teaching NOS, regardless of the context in which it was taught, could enhance student views of NOS.

**Student interest**

Lee and Erdogan’s (2007) study examining Korean physics students’ attitudes toward science utilized the Attitudes Toward Science Inventory (Enger & Yager, 1998) to quantitatively measure the differences in gains between those students experiencing a three-week SSI-based unit and those experiencing a traditional physics unit. Results found that positive attitudes toward science increased among students experiencing the SSI-based instruction, while they decreased among traditionally-taught students.
Further, the difference in student attitudes toward science was found to be statistically significant between the two instructional methods.

Through qualitative analysis of classroom discourse, Barab, et al. (2007) examined fourth graders’ level of narrative engagement during a learning module using Quest Atlantis, an online virtual environment through which students learned about environmental issues pertaining to water quality and conservation. Analysis of the ten days of classroom discourse displayed evidence of student engagement in the narrative, evidenced by their repeated referral to the online characters’ behaviors as though they were real. The authors offered numerous student quotations that showed students’ continued engagement in the Quest Atlantis narrative rather than simply in the objectives of the lesson.

The action research conducted by Yager, et al. (2006) evaluated middle school students’ attitudes toward science before and after their involvement with either an SSI-based unit or a traditional science unit using items from the Third Assessment of Science by the National Assessment of Educational Progress (1978). While both groups displayed statistically significant changes in their attitudes toward science, the attitude change for students experiencing the SSI-based instruction was positive, while the change for students experiencing the traditional instruction was negative.

Dori, et al. (2003) collected student feedback during their implementation of a module entitled Biotechnology, Environment, and Related Issues in Israeli tenth-twelfth grade Science for All classes. Student responses indicated that the students felt the SSIs discussed in the module were interesting, important, and relevant at both global and personal levels. Further, the students reported an appreciation for the variety in
teaching methods experienced through the module, and a number of students indicated an improvement in teacher-student relationships as a result of the SSI-based module.

Tal, et al. (2011) utilized student observation to gage student interest during a two-week internet-based unit on genetic inheritance. The unit allowed students to make connections between their lives and principles of genetics through the use of technology, exposure to a specific scenario involving a fictitious cystic fibrosis patient, and either a field trip to a hospital or online interaction with a CF patient. Student observations revealed that students had an increased interest in genetics and experienced enjoyment through the module’s use of technology.

**Student creativity**

Using Torrance’s (1963) definition of creativity (focusing on the acts of questioning, proposing possible answers to questions, and devising tests for determining the validity of explanations) Yager, et al. (2006) evaluated middle school students’ creativity skills following a nine-week unit that was either SSI-based or traditional. They found that students learning through the SSI-based unit “asked more questions, offered more explanations, and proposed more tests for the validation of the explanations than did students in the textbook section” (p. 254).

Lee and Erdogan (2007) utilized the Assessment of Student Creativity (Enger & Yager, 1998) to determine the impact of SSI-based and traditional learning environments on Korean physics students’ creativity. This measure includes Questioning, Reasoning, and Predicting Consequences as three subscales of creativity. The results revealed similar scores for traditionally-taught students between the pre-and post-test scores, while those for students taught through a SSI-based approach increased in the Reasoning and Predicting Consequences subscales. While there were
no statistically significant differences between the subscale post-test scores of the two groups, there were statistically significant differences between groups’ overall creativity post-test scores.

**Argumentation**

Kuhn (1991) (as cited in Thoron, 2010) defined argumentation skill as “the development of logical explanations and reorganization of opposing assertions, weights of evidence, and determination of merit for each assertion with regards to evidence” (p. 70). The notion of argumentation as a component of scientific literacy to be developed through formal education has been established by numerous researchers (Callahan, 2009; Duschl & Osborne, 2002; Newton, Driver, & Osborne, 1999; Thoron, 2010; Zeidler & Sadler, 2008). Sadler and Fowler (2006) identified the connection between SSI-based instruction and argumentation skills as contextual, stating that “a common assumption underlying [SSI-based education research] suggests that learners’ content knowledge related to the SSI under consideration significantly influences argumentation practice” (p. 3). Utilized in scientific discourse, argumentation includes articulation of justification of claims, offering of counterpositions and evidence, and social negotiation of data and theories (Sadler & Fowler, 2006). Toulmin’s (1958) works in argumentation and subsequent development of his Argument Pattern (TAP) has provided a framework through which researchers have evaluated argument structure (Sadler & Fowler, 2006; Thoron, 2010). The TAP focuses on argument structure rather than on content (Callahan, 2009), and ranks arguments based on their inclusion of data, a claim, warrants, backing, and rebuttals (Toulmin, 1958), and has been utilized as a primary tool in measuring the development of argumentation skills in education.
In their 2003 study, Dori, et al. operationalized higher order thinking skills as “cognitive activities that are beyond the level of understanding according to Bloom’s traditional taxonomy” (p. 771), and chose to measure higher order thinking skills through system thinking, question posing, and argumentation. Students’ argumentation skills were measured before and after they engaged in an SSI-based module focusing on biotechnology and genetic engineering, and were analyzed based on student academic level. All students improved in their argumentation skills, averaging an increase in arguments from pre- to posttest of 1.74. Arguments were found to relate with medical aspects, social aspects, and moral aspects most often.

Zohar and Nemet’s (2002) examined the impact of an SSI-based Genetic Revolution unit on ninth grade Israeli students’ argumentation skills through an experimental approach. Students in the experimental group, which engaged in the unit through the Genetic Revolution material, and those in the comparison group, which engaged in the same genetic principles through a traditional textbook approach, were both assessed through analysis of discussions, products developed during the classes, and written assessments. Arguments were scored according to students’ abilities to form an argument consisting of argument formulation, argument alternatives, and rebuttals, along with justification of each. Results indicated that, while students in both groups had similar pretest scores, students in the experimental group significantly improved in their argumentation skills while those in the comparison group experienced no increase in argumentation score from pretest to posttest. Response analysis also indicated that those in the experimental group were able to transfer their argumentation skills to contexts outside of the genetics dilemmas.
Jimenez-Aleixandre, et al. (2000) examined the argumentation skills of one ninth grade class in Spain during six sessions, two of which were SSI-based. Arguments were analyzed according to the argumentative operations and epistemic operations related to the development of scientific knowledge. Using TAP, the authors analyzed arguments for their data, claims, warrants to justify the connection between data and claims, warrants related to theories, qualifiers which state conditions of the claim, and rebuttals, which state conditions for discarding the claim. Epistemic operations were analyzed according a framework developed from other fields and scientific philosophy, and included induction, deduction, causality, definition, classification, use of appeals as explanation, consistency, and plausibility. Qualitative analysis indicated that student groups “developed a variety of arguments, in some cases more sophisticated...than in others” (p. 779). While groups co-constructed arguments, they also experienced unbalanced participation, wherein certain group members contributed the majority of the argument components. In all discussion, claims were the most frequently used aspects of arguments. Epistemic operations identified in student discussions included causality most often, in addition to analogies.

Tal and Hochberg (2003) assessed the argumentation skills of ninth-grade Israeli students through the use of pre and post open-ended, case-based questionnaires, portfolios, and classroom observations. Although not analyzed quantitatively, the authors found that students’ post-test arguments were longer, included more and better structured justifications, incorporated more knowledge consideration.

In an experimental study examining the impact of an SSI-based unit on eighth-grade student argumentation skills, Osborne, et al. (2004) examined students’
discussions using TAP. The experimental group was taught argumentation skills through consideration of whether a new zoo should be built while the comparison group was taught argumentation skills in a scientific context. Each of the six teachers was responsible for teaching one experimental and one comparison class. Results indicated that students in the experimental group engaged in more argumentative discourse than those in the comparison group, “suggesting that initiating argument in a scientific context is harder and more demanding both for students and their teachers, whose responsibility it is to scaffold such discourse” (p. 1007). With regard to the quality of the arguments, results indicated that while the shift was not statistically significant, students in the experimental group did exhibit an increase in their use of higher quality arguments. However, the difference in levels of argumentation between the experimental group and the comparison group was significant, with those in the experimental group exhibiting higher quality arguments after their lessons than those exhibited by the comparison group.

Sadler and Fowler (2006) identified several limitations to TAP methodologies in SSI-based education research, despite its routine use. The main limitation of scoring arguments with TAP is the subjective nature of identifying an argument’s components; “distinguishing what counts as data, warrants, and backings can be particularly tricky, leaving the reliability of TAP-based assessment schemes questionable” (p. 3). The authors stated that while some researchers have overcome this problem by grouping problematic categories together and focusing on rebuttals, this method is only useful in evaluating group discussions. In a study examining the SSI-based argumentation skills of high school and college students, Sadler and Fowler (2006) developed an
Argumentation Quality Rubric in an effort to minimize TAP’s limitations. Similar to the TAP, the rubric evaluated argument structure, but focused on claim justification, identified as the “most basic form of argumentation practices” (p. 7). Analysis of student arguments using the Argumentation Quality Rubric resulted in a statistically significant difference between groups; argumentation scores were significantly higher for science majors than for high school students or nonscience majors.

**Questioning skill**

Dori and Herscovitz’s (1999) study evaluating the question posing capabilities of varying academic levels of tenth grade Israeli students before and after an SSI-based module on air quality was conducted through researcher-developed pretests and posttests. The authors examined students’ question posing capabilities by asking them to read a case study and then “compose as many questions as he or she could ask about the case study” (p. 418). Responses were then evaluated based on the number of questions posed, the orientation of each question, and the complexity of each question. Orientations included a phenomenon and/or problem description, hazards related to the problem, and treatment and/or solution. Question complexity was measured according to its relation to the case study, as well as aspects of higher-order thinking skills and problem solving criteria. The authors found a statistically significant increase in questioning posing capabilities in all three academic groups between the pretest and posttest.

**Student Judgment of Evidence**

Kolsto’s (2001) qualitative study explored how tenth-grade Norwegian students made decisions with regard to the trustworthiness of information and knowledge claims when considering SSIs, specifically that which approaches the link between power lines
and childhood leukemia. The author defined trustworthiness as “the extent to which information and knowledge claims were seen as sufficiently reliable for inclusion in the pupils’ decision-making bases” (p. 880), which was measured via interview analysis after students read newspaper articles, research reports, and documents focusing on the issue. Inductive analysis revealed five categories related to students’ views of trustworthiness, one being conceptualized as “problems encountered”, and the remaining four being conceptualized as “resolution strategies”. Problems encountered by students were aspects that made decision making more difficult, and included disagreement among researchers, levels of research quality, and the potential for researcher bias. Resolution strategies that allowed students to make decisions in light of these problems included the immediate acceptance of specific knowledge claims, evaluation of the content of statements using reliability indicators and autonomous evaluation, acceptance of authority related to researcher confidence and confidence in other individuals and groups, and evaluation of authorities based on their opinions of risk, their self-serving interests, their level of neutrality, and their perception of competence.

**Informal reasoning**

Using both quantitative and qualitative methods, Eastwood, et al. (2011) compared the reasoning abilities of sophomore and senior students enrolled in a four-year university program centered around SSI-based education to those of biology majors at the same academic levels. Using a modified scale for argument analysis and a previously developed reasoning complexity rubric, the authors gauged students’ reasoning abilities according to “the number of justifications supporting decisions as well as whether students explained an underlying reason or mechanism for their
justifications. Results indicated that while both groups of students cited similar factors as contributing to their reasoning, students from the SSI-based program cited more factors as contributing to their decisions than the group of biology majors. Quantitative analysis displayed a significant difference between reasoning scores of the two majors. The results of reasoning between the two groups differed, as biology majors were more likely to support limits on carbon emissions, which is a commonly offered solution to issues of global warming, while SSI-based program students were more likely to offer alternative and innovative solutions. This and other differences between the two groups' decisions led the authors to posit that “SSI students viewed the problem [of global warming] as more complex than the BIO groups” (p. 112). Finally, when analyzing the reasoning scores quantitatively, scores were found to be significantly higher for SSI students.

**Socioscientific reasoning**

Barab, et al. (2007) examined students' patterns of socioscientific reasoning during their experiences with Quest Atlantis through student products created during the “quests”. The authors found evidence of high socioscientific reasoning through students’ balancing of ecological and economic concerns, presentation of strengths and weaknesses, consideration of scientific data, and consideration of multiple lines of evidence. Alternatively, they also found evidence of weaknesses in socioscientific reasoning through inconsistencies between conclusions and solutions, inaccurate scientific assumptions, and underestimations of social impacts.

Sadler, et al. (2011) analyzed students’ socioscientific reasoning abilities before and after the implementation of a SSI-based unit on global climate change in high school environmental science and chemistry classes. A researcher-developed rubric
characterized student responses into five different levels of reasoning, the lowest signifying that the student feels no additional inquiry in necessary and the highest level signifying that additional inquiry is needed in at least three areas. Results indicated that there were no statically significant differences between the pretest and posttest scores of socioscientific reasoning, leading the authors to recommend that further research be conducted to determine the variable aspects of SSI-based instruction that could cause change in student socioscientific reasoning.

Reflective thinking

Reflective thinking skills are a component of higher-order thinking skills and require students to weigh consequences of potential problem solutions (Tal & Hochberg, 2003). Tal and Hochberg (2003) examined the impact of a WISE module focusing on malaria on the reflective thinking skills of ninth grade Israeli students. The authors measured the reflective thinking present in students’ written and spoken arguments according to their incorporation of suggestions, ideas, hypotheses, explanations, feelings, and personal views. Qualitative analysis revealed that students had not had the opportunity to discuss their feelings in science class previously. Five dimensions of reflective thinking were revealed through student responses: (a) affective, which focused on students’ feelings; (b) social, which focused on social aspects of the dilemma; (c) cognitive, which focused on the identification of a social need, criticism, and the suggestion of solutions; (d) affective-social, which focused on the connections between personal feelings and the difficulties of others; and (e) cognitive-social, which focused on a desire to find a culture-related solution. While cognitive-social reflection was evident less often than any of the five other dimensions, the authors attributed this to the short scope of the project. Responses also revealed that more correct
statements, as well as more statements in cognitive and cognitive-social dimensions were expressed toward the end of the project, implying that exposure to the SSI module enabled students to reflect more holistically as time progressed.

**Problem solving**

Using a four-stage analysis, Tal and Hochberg (2003) assessed ninth-grade Israeli students’ problem solving capabilities during an internet-based SSI unit focusing on the spread of malaria. The problem-solving instrument consisted of one item: “What do you think the best approach is to controlling Malaria?” (p. 11). The authors analyzed student written responses according to the students’ ability to identify the problem, provide a coherent description of the problem, evaluate alternatives, and suggest a rational/valid solution. These were broken down further into two levels of complexity: “at the low level, the student provided a partial description, incorrect information, irrational, or unpractical solution. At the high level, the student provided a correct and supported description of the problem; formulated a creative or innovative solution, or synthesized existing solutions. Results indicated that high complexity solutions were much more common than those of low complexity at each of the four stages of problem solving. The highest skills were found in describing the problem coherently and in evaluating supplied solutions. The authors posit that WISE’s “well-structured” activities may have been the cause of these high skill categories, and suggest that “less structured activities might lead to higher problem solving capabilities [since] a few students stated that ‘the answers were already there, so I did not have to bother too much to come up with my own solutions’” (p. 11).
Scientific inquiry

The study by Barab, et al. (2007) investigated students’ experiences using Quest Atlantis and revealed enhanced scientific inquiry. While the “quests” of the module guided student inquiry through the initial presentation of a problem, forced consideration of the problem’s multiple facets, and guided experimentation to develop solutions, the authors noted that “it was clear in observing students that the inquiry component of the experience was not simply a scientific process, but one that was very social and involved understanding people. We would argue that this framing, in part, turned the experience from a purely scientific one to a lived experience that deeply engaged the students and led to rich social negotiations” (p. 71).

Summary

The goal of Chapter 2 was to provide the theoretical and conceptual frameworks which guided the overall study. Also included in Chapter 2 was a review of the salient research pertaining to the various aspects of the conceptual framework guiding this study. The literature review focused on teacher formative and training experiences and properties that impact SSI-based education, student formative experiences and properties that impact their learning during SSI-based instruction, the types of experiences had by students during SSI-based instruction, and the short term outcomes of SSI-based instruction.

Studies have largely focused on the immediate outcomes of SSI-based education due to its relatively short history in educational practice. Design elements included a variety of SSIs, including those that are related to the environment, health, genetics, and animals. These SSI units have been incorporated into a variety of science subjects at a range of grade levels, yet have not been implemented outside the realm of science
classes. Outcomes of SSI-based instruction have included increases and improvement in a variety of aspects related to scientific literacy, including science content knowledge, argumentation skills, views of the NOS, student interest, creativity, and higher order thinking skills such as questioning, reasoning, inquiry, problem solving, reflective thinking, and judgment of evidence.

While these outcomes have offered promising results indicating the potential benefits of SSI-based education, implementation into agricultural education will require an understanding of the presage variables impacting the instruction, such as teacher formative and training experiences and perceptions regarding SSI-based instruction. These variables have rarely been the focus of SSI-based education research; the few studies examining them hinted that teachers appreciate the value of SSI-based instruction but may experience barriers that hinder their abilities to successfully incorporate SSI-based instruction into their classes.
Figure 2-1. Model of the Experiential Learning Process (Kolb, 1984).

Figure 2-2. Framework for SSI-Based Education (Sadler, 2011).
Figure 2-3. A model for the study of classroom teaching (Dunkin & Biddle, 1974).

Figure 2-4. Conceptual Model of SSI-based Instruction
Chapter 1 explained the need for the development of scientific literacy among high school agriculture students, as well as introduced socioscientific issues (SSI)-based education as a vehicle for increasing students' scientific literacy. The purpose of this study was to determine the effects of SSI-based instruction on student content knowledge achievement, argumentation skills, scientific reasoning, and views of the nature of science (NOS).

Chapter 2 provided the study’s theoretical and conceptual frameworks, as well as highlighted the important research related to the study’s conceptual framework. Theories guiding this study were constructivism, experiential learning, and problem solving, as well as Sadler’s (2011) framework for socioscientific issues based education and Dunkin & Biddle’s (1974) model for the study of classroom teaching. A review of the literature aligning with the study’s conceptual framework focused on teacher, student and contextual aspects that influence SSI-based instruction, the design aspects of SSI-based instruction, and student gains in knowledge, argumentation, interest in science, reasoning skills, views of the NOS, and problem solving ability as a result of SSI-based instruction.

Chapter 3 details the methods utilized to address the study’s research questions. In doing so, the chapter provides information on the research design, procedures, population and sample, intervention, instrumentation, data collection procedures, and methods of data analysis. The chapter also distinguishes between the designed procedures of the study and those that were practiced during the study, as the social
nature of this study resulted in some practices which deviated from those originally designed.

**Population and Sample**

The study’s population was Florida secondary agriscience students. The sampling frame consisted of students of a convenience sample of Florida agriscience teachers. Teachers had to be teaching at least one Agriscience Foundations class during the 2011-2012 year. These classes could be at the middle or high school level, and could consist of students in eighth through twelfth grades.

The student sample size was calculated according to Hays’ (1973) formula for calculating a sample size resulting in practical and statistical significance, while avoiding significance due to inflated sample size:

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

This formula was used to achieve an alpha level of .05, achieve a power of .90, and detect variance associated with the independent variable at a level greater than .10 (Hays, 1973). The formula utilizes the z-score for the desired alpha level \(Z_{(1-\alpha/2)}\), that for the desired power \(Z_\beta\), and the effect size in units of standard deviation \(\Delta\) to determine the sample size. The effect size in units of standard deviation is calculated via the following formula:

\[ \Delta = 2\sqrt{w^2 / (1 - w^2)} \]

In this formula, the amount of variance in the dependent variable accounted for by the independent variable \(w^2\) is utilized to calculate effect size in standard deviation units.

Based on Hays’ (1973) formula, the calculations performed for this study are as follows:

\[ \Delta = 2\sqrt{.01/(1-.10)} = .66 \]

\[ n = 2[1.96-(-1.64)]^2 / .66^2 = 59.5 \]
Thoron (2010) noted that similar studies “may experience a mortality rate up to 50%...even when controlled properly by the researcher” (p. 96) (Boone, 1988; Dyer, 1995; Flowers, 1986, & Myers, 2004). Therefore, the calculated sample size \((n = 60)\) was doubled \(\left(n = 120\right)\). An estimate of 12 students per class has been utilized in similar previous studies involving intact classes of agriscience students (Thoron, 2010), and was therefore deemed appropriate for this study. These calculations resulted in a teacher sample size of 10.

Teachers were recruited via convenience sampling methods. Those teachers participating in the Florida Association of Agricultural Educators Summer Conference and regional FFA Chapter Officer Leadership Conferences were recruited to attend training sessions related to the study. The teachers attending the summer conference were offered an in-person training session, while those attending the leadership conferences attended one of four online training sessions.

**Research Design and Procedures**

This study utilized a pre-experimental, single group pretest-posttest design (Campbell & Stanley, 1963), illustrated below.

\[
O_1 \times O_2
\]

Because of the theory building nature of this study, a true experimental or quasi-experimental design was not deemed appropriate. Theory building, “the purposeful process...by which coherent descriptions, explanations, and representations of observed or experienced phenomena are generated, verified, or refined,” (Lynham, 2000, p. 161), is guided in design by the nature and development of the theory rather than by a researcher’s preferred method of inquiry (Lynham, 2002). While single group pretest-posttest designs are susceptible to numerous threats to internal validity, the use
of a control group to compare the effect of the intervention to other interventions (including no intervention) was deemed preemptive, as SSI-based instruction use has not yet been documented in agricultural education.

**Designed Procedures**

The first observation consisted of a series of pretests administered to students to determine baseline content knowledge, argumentation skills, views of the NOS, and scientific reasoning ability. Following the treatment, the second observation consisted of posttests measuring the same items. Student content knowledge was measured at intervals throughout the treatment. The study's design is illustrated below:

\[
\begin{align*}
O_{\text{CkPreAg}} & \quad O_{\text{SRPre}} & \quad O_{\text{ArgPre}} & \quad O_{\text{NoSPre}} & \quad O_{\text{PreFS}} \\
X_{\text{FS}} & \quad O_{\text{CkPostFS}} & \quad O_{\text{CkPreEc}} & \quad X_{\text{Ec}} & \quad O_{\text{CkPostEc}} & \quad O_{\text{CkPreEnv}} & \quad X_{\text{Env}} & \quad O_{\text{CkPostEnv}} & \quad O_{\text{CkPreAn}} & \quad X_{\text{An}} \\
O_{\text{CkPostAn}} & \quad O_{\text{CkPostAg}} & \quad O_{\text{SRPost}} & \quad O_{\text{ArgPost}} & \quad O_{\text{NoSPost}}
\end{align*}
\]

**Key:**

- **Pre** - Pretest
- **Post** - Posttest
- **Ck** - Content Knowledge Assessment
- **SR** - Scientific Reasoning – (LCTSR)
- **Arg** - Argumentation – (Sadler’s 2006 Rubric)
- **Nos** – NOS – (Chen’s 2006 Views of Science and Education Questionnaire)
- **X** – Treatment
- **Ag** – Overall Agriscience Content
- **FS** – Food Safety (6 lessons)
- **Ec** – Economic Aspects (11 lessons)
- **Env** – Environmental Aspects (11 lessons)
- **An** – Animal Industry (17 lessons)

During the first observation, students were administered pretests that measured their overall agriscience content knowledge \((O_{\text{CkPreAg}})\), scientific reasoning ability \((O_{\text{SRPre}})\), argumentation skills \((O_{\text{ArgPre}})\), and views of the NOS \((O_{\text{NoSPre}})\). Their knowledge of food safety was also assessed \((O_{\text{PreFS}})\) to provide baseline content knowledge data prior to the first treatment unit, Food Safety. Students then experienced the Food Safety
treatment unit \((X_{FS})\). Following completion of the first treatment unit, students’ knowledge gains in agriscience content related to food safety were measured through a Food Safety posttest \((O_{CkPostFS})\). Students were then assessed on baseline knowledge of agriscience content related to economics through the unit pretest \((O_{CkPreEc})\). This cycle of pretesting, treatment, and posttesting was repeated through each of the study units. The final observation consisted of posttests to measure students’ agriscience content knowledge related to animal science, overall agriscience content knowledge, scientific reasoning ability, argumentation skill, and views of the NOS.

**Practiced Procedures**

While the study’s procedures were followed according to the designed order, teachers were unable to deliver all lessons to students during the practiced duration of 14 weeks. The study’s practiced procedures are illustrated below:

\[
O_{CkPreAg} O_{SRPre} O_{ArgPre} O_{NoSPre} O_{PreFS} \\
X_{FS} O_{CkPostFS} O_{CkPreEc} X_{Ec} O_{CkPostEc} O_{CkPreEnv} X_{Env} \\
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All teachers completed the Food Safety, Economic Impacts, and Environmental Impacts units, and no teachers conducted any lessons in the Animal Industry unit. Therefore, pretests and posttests aligned with the Animal Industry unit were not administered. Additionally, items on the distal content knowledge assessment aligning with the Animal Industry unit were removed.

**Threats to Internal Validity**

As mentioned previously, the single group pretest-posttest design is susceptible to numerous internal validity threats. Campbell and Stanley (1963) identified five threats uncontrolled by this design: history, maturation, testing, instrumentation, and interaction.
of selection and other threats. The use of multiple classrooms reduces the threat of history, as “an event should have occurred to most of the students in the group under study” (Campbell & Stanley, 1963, p. 7), which reduces the threat of historical events occurring within a classroom. Historical events with broader geographical impact remained a threat in this study, although no events are known to have occurred. The threat of maturation was reduced in this study through the selection of a class subject containing a range of student ages, as students did not experience similar maturation based on age. Instrumentation threats, identified as “changes in the calibration of a measuring instrument” (Cook & Campbell, 1986, p. 153), were not a threat to the assessments, as they remained identical between the pretest and posttest. Finally, interaction of selection and other threats was reduced through the use of multiple classes and the collection of covariate data in order to control for differences between classes.

Additional threats associated with the study included teacher variables that could potentially impact observed outcomes (Thoron, 2010). This study examined the impact of an instructional model in more than one classroom, administered by different teachers, thereby controlling for individual teacher differences. Fidelity of treatment was established through a professional development session to train teachers in the use of the intervention (Boone, 1988; Hennessey & Rumrill, 2003). The session introduced teachers to SSI-based instruction, explained the components of SSI-based instruction and differences between SSI-based instruction and subject matter-based instruction. Differences between the two types of instruction enabled teachers to focus on how their behavior, teaching style, and classroom management may differ. Teachers were also
introduced to the study’s components, including all content, lessons, and assessments. Finally, teachers were introduced to the SSI that was the focus of the study’s intervention, which was the production of laboratory-grown meat as a food source. Lesson plans were also designed to increase fidelity of treatment by providing easy-to-access resources and instructions and recommending specified lengths of time for each classroom activity (Lane, Bocian, MacMillan, & Gresham, 2004).

Selection of content is “a concern with conducting a study utilizing specific teaching methods” (Thoron, 2010, p. 91). The lesson plans, their content, and their strategies were reviewed by a panel of experts in agricultural and science education and were deemed to be appropriate for use in teaching Agriscience Foundations standards and in teaching through SSI-based instructional methods.

Finally, the selection of a convenience sample was considered a threat in this study, and generalization of the findings was limited. However, because of the theory-building nature of the study, the ability to make generalizations was not considered a primary goal of the research.

**Designed measures to reduce validity threats**

Teachers were provided with audio recorders and instructions to record each class session so a random selection of 25% of the recordings could be analyzed to further ensure treatment fidelity (Thoron, 2010). Recordings were to be analyzed by the researcher according to the number of practiced activities that aligned with those provided in the lesson plans. All lessons with 80% alignment were to be deemed to be acceptable, and teachers with 90% of their lessons meeting acceptable alignment were to be included in the study.
During training sessions, teachers were informed of their responsibility to supply the researcher with daily attendance records so that students missing over 25% of the instructional time could be removed from the study, as has been recommended in studies of a similar nature (Thoron, 2010).

**Practiced measures to reduce validity threats**

After weekly reminders in both electronic format and via telephone contacts, teachers failed to consistently record their classes, citing forgetfulness and technical difficulties as justification. Therefore, recordings could not be utilized to ensure fidelity of treatment. Informal conversations with teachers during routine contacts and the production of student work required by the lessons implied that teachers followed lesson plans as designed; however, the threat of treatment fidelity was not able to be reduced through measures for monitoring practice in this study.

After repeated contacts and reminders, teachers also failed to consistently share attendance records. The inability to adjust mortality rate to account for those receiving less than 75% of the instruction is considered a limitation in this study.

**Intervention**

The intervention for this study consisted of lessons which taught agriscience content through an SSI context. The segment was broken down into five instructional units, each examining the SSI from a different perspective: (a) food safety, (b) economic impacts, (c) environmental impacts, (d) the animal industry, and (e) introduction of cultured meat.

**Designed Duration**

Forty-five lesson plans were developed to accommodate 45-minute classes, leading to a total of nine weeks of lessons. Teachers teaching on block schedules were
instructed to utilize two lessons per class period, resulting in the same amount of instructional time in all classrooms being devoted to the lessons. Because of both previously known events attended by most secondary agriscience teachers, such as National FFA Convention, and potential unforeseen circumstances occurring at the various schools, teachers were instructed to complete the nine weeks of lesson plans in a 12-week time period.

**Practiced Duration**

Teachers were contacted on at least a weekly basis via email or telephone, with teachers that appeared to be struggling or unable to be reached being contacted more frequently. Toward the conclusion of the 12-week time period during which teachers were to deliver all 45 lessons, all teachers participating in the study requested more time to complete their lesson plans. In an effort to conclude the study with as much data as possible, teachers were granted two additional instructional weeks, resulting in a final study duration of 14 weeks.

**Instructional Plans**

All instructional plans (Appendix A) were developed according to recommended practices of experiential learning (Kolb, 1984), SSI-based instruction (Sadler, 2011), and inquiry-based instruction (NRC, 2000). Plans were evaluated for content validity by a panel of experts in agricultural education, experiential learning, inquiry-based instruction, and SSI-based instruction from the University of Florida’s Department of Agricultural Education and Communication and School of Teaching and Learning. Lessons were accompanied by unit guidelines that included all content intended to be taught in the lessons (Appendix B).
**Socioscientific issue**

SSI was operationalized for this study as the inclusion of lab-grown meat into the nation’s food source. This SSI selected for this nine-week instructional component was chosen with consideration of recommended aspects of SSIs. By definition, SSIs should confront students with situations in which scientists are seen not to be in agreement (Albe, 2008). Sadler (2004) recommended that appropriate SSIs be selected based on their relevance to students’ personal lives, foundations in scientific factors, position as a focus of societal interest, and makeup as “complex, open-ended, often contentious dilemmas, with no definitive answers” (p. 514). Societal issues focusing on genetic engineering have been utilized in numerous studies examining the use of SSI-based instruction (Dori, et al., 2003; Jiminez-Aleixandre, et al., 2000; Sadler & Zeidler, 2004; Zohar & Nemet, 2002), and was chosen as the overarching SSI area according to its connection with Agriscience Foundations Student Performance Standards.

**Designed instructional units**

The instructional units were developed by the researcher and reviewed by a panel of experts in both agricultural education and SSI-based instruction. The content was selected based on 22 Student Performance Standards listed for Agriscience Foundations by the Florida Department of Education. The researcher then grouped these standards by topic and selected content appropriate for the grade level of the students, the course description, the purposes of agricultural education, and the context of a specific SSI.

Five individual units were created according to the groupings of Student Performance Standards and their relationship to the SSI (Appendix C). Four of the units were taught in consecutive order for specific lengths of time appropriate to their included
content. The fifth unit specifically addressed students’ reflection of the SSI and the content they had learned thus far, and lessons from this unit were dispersed throughout the other units (Appendix D). Individual lessons were designed to require 45 minutes of instructional time. Teachers were given permission to adjust the recommended duration of activities, as they were considered the experts in their students’ abilities.

**Practiced instructional units**

Based on student differences and the time constraints of the study, no teachers were able to complete all of the 45 lessons provided. Students were exposed to 34, 35, or 37 of the 45 lessons based on their teachers’ ability to guide them through the consecutive lessons throughout the study’s duration. Completion of these lessons indicated that students were exposed to four of the five units; no student was exposed to lessons from the Animal Industry unit.

**Lesson Procedures**

Lessons each began with an interest approach that lasted between five and 10 minutes. Interest approaches were designed in a manner that allowed students to become acquainted with the lesson’s topic, link previous lessons with the upcoming lesson, and understand the relevance of the topic in their lives. The interest approaches were each supplemented with guiding questions to aid the teacher in the stimulation of appropriate discussion. For example, the first lesson of the Food Safety unit began with an introduction that introduced students to the FDA’s “Current Meat and Poultry Recalls” webpage. Guiding questions included, “How many recalls were there since the beginning of the school year? What are some common reasons listed for the foods being recalled? Do you think you may have eaten any of these products?”
Following the interest approach, the lessons were broken up into one to three learning activities ranging in duration from 35 to 35 minutes. Activities were designed to introduce students to new concepts, enable reflection about the concepts, allow for practice and application, and encourage decision-making. Guiding questions supplemented each learning activity to guide appropriate discussion. Each lesson plan activity was accompanied by a brief content outline to aid the teacher in adhering to specific content intended to be included in the lesson. The first day of the Food Safety unit included a learning activity that required students to make decisions about the legitimacy of public safety concerns while they learned about food safety concerns in history. Guiding questions included, “Why do you feel that concern is justified/unjustified? Why do you think people are concerned if the concern is unjustified?”

Upon the conclusion of the learning activities, each lesson ended with a summary activity lasting between five and 15 minutes. These activities were designed to review new concepts, encourage reflection, and require decision-making by the students. For example, the Food Safety unit’s first lesson was concluded with the evaluation of a list of genetically modified organism benefits and drawbacks. Students were instructed to indicate whether they thought each genetically modified organism was more beneficial or detrimental to society based on their listed benefits and drawbacks, which were introduced during the lesson. Students defended their choices, and submitted their arguments to the teacher.

Each lesson plan also included a section that detailed the evaluation methods of the lesson to aid teachers in assessing students on their knowledge. The lessons also
included a section that stated any items to be turned in to the researcher to ease the
teacher burden of identifying items to be returned. All supplemental materials, including
powerpoints, notes, and worksheets, accompanied each lesson plan.

Instrumentation

Researcher-developed instruments were utilized to evaluate students’ overall and
unit-specific agriscience content knowledge. Argumentation skills, scientific reasoning,
and views of the NOS were measured through the Argumentation Quality Rubric
(Sadler, & Fowler, 2006), Lawson’s Classroom Test of Scientific Reasoning (LCTSR)
(Lawson, 1978, as supplied in Thoron, 2010), and the Views on Science and Education
Questionnaire (VOSE) (Chen, 2006).

Content Knowledge Achievement Assessment Instrument

Student agriscience content knowledge was measured through the use of proximal
assessments, which measured students’ knowledge on content related to each unit, and
a distal assessment, which measured students’ content knowledge on the entire
treatment.

Designed assessments

Four unit-specific assessments were developed by the researcher to align with
each of the four consecutive units taught during the treatment: (a) Food Safety, (b)
Economic Impacts, (c) Environmental Impacts, and (d) the Animal Industry. All tests
were similar in design and difficulty. The unit-specific assessments consisted of items
appearing on the Florida Agritechnology Industry Certification Exam which aligned with
the standards utilized for the intervention (Table 3-1). These were supplemented with
researcher-developed questions to adequately assess each standard. Content
knowledge of the standards from the Animal Industry unit, consisting of three weeks of
lessons, was intended to be assessed with 30 items, while each of the other units, consisting of one or two weeks of lesson plans, was assessed with 20 items.

The distal assessment was constructed with questions from the unit assessments, and consisted of 10 items per unit for a total for 40 items. The students were assessed using pretests and posttests, which were identical (Appendix E); students did not receive feedback on their performance on the pretests before taking the posttests. Content and face validity were established through an expert panel of faculty members of the University of Florida’s Department of Agricultural Education and Communication. A pilot test was conducted utilizing 15 University of Florida juniors in Agricultural Education to establish reliability. Analysis of the items resulted in the following Kuder-Richardson 20 scores, which is appropriate for dichotomous data (Huck, 2008):

- Food Safety: .61
- Economic Impacts: .37
- Environmental Impacts: .60
- Animal Industry: .65

Removal of identified questions resulted in the following Kuder-Richardson 20 scores, which is appropriate for dichotomous data (Huck, 2008):

- Food Safety: .77
- Economic Impacts: .66
- Environmental Impacts: .72
- Animal Industry: .77

**Practiced assessments**

Because no students were exposed to lessons from the Animal Industry unit, the Animal Industry pretest and posttest were not utilized in this study. Further, all items on the distal assessment aligning with the Animal Industry unit were removed, as students
were not exposed to this content. This removal of items resulted in a 30-item distal assessment.

**Lawson’s Classroom Test of Scientific Reasoning**

Students’ scientific reasoning ability was assessed before and after the intervention through the use of Lawson’s Classroom Test of Scientific Reasoning (1978), as it is “considered a reliable and valid instrument that measures level of formal-operational scientific reasoning in secondary and college-age students” (Thoron, 2010, p. 98). Through the use of 24 questions that require higher-order thinking, the LCTSR measures students’ formal scientific reasoning abilities. Validity was established for the original version of the LCTSR (Lawson, 1978) through review of an expert panel, who established that the test items require students to utilize formal reasoning skills. During the development of the instrument, a Cronbach’s alpha coefficient of .86 was calculated to establish reliability. Because the instrument was designed for post-secondary students, the developer also established reliability for grade levels 8, 9, and 10 through a Kuder-Richardson 20 calculation, which was reported as .78 (Lawson, 1978). A multiple-choice version of the test written by Lawson (1978) and provided in Thoron (2010) was utilized via paper and pencil administration in this study (Appendix F). Student responses were scored by the researcher through the use of an answer key developed by Lawson.

**Argumentation Quality Rubric**

Students’ argumentation skill was assessed through the Argumentation Quality Rubric (Appendix G) (Sadler & Fowler, 2006). This rubric was developed for use with students experiencing SSI-based education following limitations of Toulmin’s Argumentation Rubric (TAP) (1958) found in similar studies. The Argumentation Quality
Rubric overcomes difficulties in categorizing claims, warrants and backings by focusing strictly on the justification of claims, which is critically important to argumentation (Sadler & Fowler, 2006). During the rubric’s development, Sadler & Fowler utilized inductive analysis of a small data set to “refine the rubric and clarify distinctions between the levels within the rubric” (p. 8). Reliability of the rubric was established by Sadler & Fowler (2006) through the use of multiple scorers, which resulted in an inter-rater consistency above .9. In the current study, students responded to researcher-developed scenarios directly related to the intervention’s SSI (Appendix H) in a paper-based open response format for a pretest and posttest. Face and content validity of the scenarios were established through review by an expert panel consisting of faculty members and graduate assistants of the University of Florida’s Department of Agricultural Education and Communication and School of Teaching and Learning. Interrater reliability of response scores was calculated through the use of multiple scorers consisting of researchers in the University of Florida’s Department of Agricultural Education and Communication. The primary researcher individually scored each scenario response, and scores on 10% of the responses were analyzed and confirmed by a secondary researcher who confirmed the primary researcher’s scores (Lincoln & Guba, 1985).

**Views on Science and Education Questionnaire**

Students’ views of NOS were assessed via pretests and posttests using the VOSE (Appendix I) (Chen, 2006). This assessment was developed in an effort to overcome limitations by previous quantitative instruments measuring views of NOS, which forced students to choose between overly-generalized, expert-produced responses that did not fully encompass all possible viewpoints of NOS (Chen, 2006). These limitations of
previous instruments have caused many researchers to examine views of NOS through qualitative methods, which reduce researcher objectivity and require participants to fully articulate their views in a limited amount of time (Chen, 2006). The VOSE includes items developed through empirical means rather than from expert recommendations, includes Likert-type scales for each of the items, and is written in the context of NOS issues taken from a review of literature. The VOSE measures student views on seven NOS aspects: (a) tentativeness of scientific knowledge; (b) observations are theory laden; (c) varying scientific methods; (d) the differences between hypotheses, laws, and theories; (e) imagination is used when generating scientific knowledge; (f) validation of scientific knowledge; and (g) objectivity and subjectivity in science. Content validity was established for the assessment’s original version, written in Chinese, through the use of two separate expert panels and interviews with students to verify item clarity. Based on Chen’s (2006) recommendations, the researcher modified the English version of the assessment to include language appropriate for American high school students, and established face and content validity through a panel of experts consisting of faculty members and research assistants in the University of Florida’s Department of Agricultural Education and Communication. Test-retest reliability was established by the developer with a coefficient of .82. Because of the empirical nature of the instrument, the establishment of internal consistency reliability was not appropriate (Chen, 2006).

Chen (2006) recommended that the researcher analyze data according to the views thought to be superior in the study. Recommendations stated that item responses can be coded in a straight-forward fashion or in reverse. Because this study did not
explicitly instruct students on superior or inferior views of the nature of science, responses are reported in descriptive fashion and were not coded or indexed.

**Data Analysis**

Data were analyzed through SPSS version 20. Data corresponding to each objective were analyzed through the use of paired-samples $t$ tests, which has been deemed appropriate for use in measuring the gains of a group between two tests administrations (Agresti & Findlay, 2009). For the analysis of content knowledge gains, each unit test and the overall test were analyzed separately, as each test includes a pretest and posttest administration. Scores were also analyzed based on school level to determine differences between middle school and high school students. The effect sizes of any statistically significant values were calculated and interpreted according to Cohen’s $d$.

**Summary**

Chapter 3 detailed the methods utilized in this study through a reporting of the research design and procedures, methods of addressing threats to validity and fidelity, population and sample, instrumentation, data collection instruments and procedures, and data analysis.

The study’s independent variable was the teaching method utilized in Agriscience Foundations classes. The intervention was a nine-week unit utilizing SSI-based instruction. The dependent variables in the study were students’ agriscience content knowledge, argumentation skills, scientific reasoning ability, and views of the NOS. Both presage variables and context variables were considered antecedent variables and were, therefore, treated as static attributes.
The study employed a pre-experimental, single group, pretest-posttest design, which was deemed appropriate due to the theory-building nature of the study. The population of the study consisted of Florida agriscience students. Students were accessible through their Agriscience Foundations classes; Agriscience Foundations teachers were recruited through convenience sampling. Students in ten classes experienced the treatment, which consisted of a nine-week unit in the context of an SSI. The SSI chosen for this study was the introduction of cultured meat into the nation’s food supply.

Student gains as a result of the intervention were calculated through the use of pretests and posttests measuring each of the four dependent variables. Agriscience content knowledge was measured through researcher-developed instruments, argumentation skill was measured through the Argumentation Quality Rubric, scientific reasoning ability was measured through Lawson’s Classroom Test of Scientific Reasoning, and views of the NOS were measured through the Views of Science and Education Questionnaire. Data were analyzed using SPSS 20 and included the calculation of means, frequencies, standard deviations, and dependent samples $t$ tests.
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*Note.* SSI = objectives pertaining to SSI; * = objectives with content repeated from previous lessons; All = objectives pertaining to the entire unit; Arg = objectives pertaining to the development of argumentation skills.
CHAPTER 4
RESULTS

Chapter 1 established the need for improving secondary agriscience students’ scientific literacy through problem-based teaching methods. This study aimed to determine the impact of a socioscientific issues (SSI)-based instructional unit on student agriculture content knowledge, scientific reasoning ability, argumentation skill, and views of the nature of science (NOS).

The purpose of Chapter 2 was to provide a theoretical and conceptual framework through which the study was developed. Theoretical underpinnings of the study included constructivism, experiential learning, problem solving, and SSI-based instruction. A review of literature included in Chapter 2 examined studies focusing on the presage, context, process, and product variables impacting student learning during SSI-based instruction.

Chapter 3 detailed the methods through which the study was conducted. Using a convenience sample secondary agriculture students enrolled in Agriscience Foundations, a pre-experimental, single group pretest-posttest design incorporated a nine-week SSI-based instructional unit into Agriscience Foundations classes. Data was collected through four separate instruments and analyzed through the use of paired-samples t tests and descriptive statistics.

Findings of the study are presented in Chapter 4. Following the study’s objectives and hypotheses, results regarding the impact of the SSI-based instructional unit on students’ agriscience content knowledge, scientific reasoning ability, argumentation skills, and views of the NOS are reported.
Sample

The population for the study was Florida’s agriscience students; the accessible population was those students enrolled in an Agriscience Foundations class. A convenience sample was collected from teachers participating in the Florida Association of Agricultural Educators Summer Conference and regional FFA Chapter Officer Leadership Conferences. Approximately 40 teachers attended the training sessions, which were provided to inform potential participants about the study. Eleven teachers expressed interest in the study and signed consent forms (Appendix J), leading to a total of 672 students enrolled with signed consent forms (Appendix K). After extensive and repeated communication with the researcher, five teachers asked to be removed from the study after its start due to complications arising during the school year, such as a large number of days out of the classroom, increased responsibilities from administration, and unforeseen time requirements while mentoring new fellow teachers. One teacher was removed from the study because of a career change mid-semester, and so he was no longer eligible to participate. One teacher was removed from the study after completing eight lessons during the 14-week period, which was deemed to be too few to make a marked impact on students’ learning. Four teachers’ classes participated in the entire study, resulting in 115 total students (Table 4-1).

Teacher Demographics

Table 4-1 displays demographic information for teachers who remained in the study for its entirety. Three of the four teachers were female. The teachers had a range of teaching experience between one and 19 years, with all holding bachelor’s degrees and half holding master’s degrees. Three of the teachers attended the distance training session while one attended the face-to-face session. All four of the teachers reported
having no previous familiarity with the study’s SSI, cultured meat. Teachers’ reported level of experience with SSI-based instruction was not at all experienced for three teachers and slightly experienced for one teacher. With regard to complementary teaching methods, two teachers reported being very experienced in experiential learning, while one teacher reported being somewhat experienced and one reported being not at all experienced. Two teachers reported being very experienced in inquiry-based instruction. One teacher reported being neither experienced nor inexperienced in inquiry-based instruction, while the fourth reported being somewhat experienced. Three teachers reported being somewhat experienced in problem solving instruction, while one reported being neither experienced nor inexperienced. One teacher reported being slightly experienced in SSI-based instruction, while the other three teachers reported being not at all experienced. Three of the teachers taught in rural settings, while one taught in an urban setting. Two of the rural settings were high schools, while one middle school was in a rural setting and one was in an urban setting. The teacher in the urban middle school had two Agriscience Foundations classes enrolled in the study, totaling 48 students. The remaining three teachers each had one class participating, with student numbers of 25 (high school), 13 (high school), and 29 (middle school).

**Student Demographics**

Table 4-2 displays student demographic data. Eighth-grade students made up 67% of the sample ($n = 77$), and comprised both classrooms of Teacher A and the classroom of Teacher B. All middle school students were in the 8th grade. Thirty-five students (30.4%) were in ninth grade and made up Teacher C’s entire classroom, as well as the majority of Teacher D’s classroom. One student in Teacher D’s classroom
was in 11th grade and one was in 12th grade. Ninth-graders comprised 92% of the high school students.

One of Teacher A’s class had a majority of female students (72%, n = 18), while the other had a makeup of 43.5% females (n = 10). Teacher B’s class was comprised of 37.9% female (n = 11). Teacher C’s class was 43.5% female (n = 10), while females made up 53.8% (n = 7) of Teacher D’s class. Overall, 48.7% of the study’s participants were female.

**Response**

After multiple contacts, several teachers failed to send all of the completed instruments. Table 4-2 displays the specific assessments each teacher returned, as well as the assessments each student completed. The number of students reported for each assessment varied. Students were included in each data analysis if they completed a pretest and posttest for that specific instrument; they were not omitted from all data analysis if they were missing a specific pretest or posttest. Teacher A submitted classroom sets of the distal agriscience content, scientific reasoning, argumentation, and views of the NOS pretests, but failed to return posttests for each of these assessments. Therefore, the class’ pretest scores were not included in the data analysis. Teacher A did return both pretests and posttests for each of the three proximal content knowledge assessments, so the class’ scores were included in data analysis for each of the proximal exams. Teacher C submitted all proximal pretests and posttests, as well as the argumentation pretest and posttest. Due to the teacher’s failure to return posttests for distal agriscience content knowledge, scientific reasoning, and views of the NOS, Teacher C’s class scores were omitted from analysis of these measures. Teacher
B and Teacher D submitted all pretests and posttests; all students who completed the pretests and posttests were included in data analysis.

Agriscience content was measured through pretests and posttests of overall content knowledge and unit-based assessments (Table 4-3). Eighty students (69.6%) completed the overall content knowledge pretest, while 39 (33.9%) completed the respective posttest, leading to a pretest-posttest completion rate of 48.8%. Unit-based pretests and posttests were conducted for each of the study’s four units. One hundred-six students (92.2%) completed the Food Safety pretest, while 98 (85.2%) completed the posttest, resulting in a pretest-posttest completion rate of 92.5%. The Economic Impacts pretest was completed by 109 students (94.8%) and the posttest was completed by 102 students (88.7%), leading to a 93.6% pretest-posttest completion rate. Environmental Impacts pretests were administered to 108 students (93.9%) while posttests were administered to 99 students (86.1%), resulting in a pretest-posttest completion rate of 91.7%. Because no teacher was able to begin delivering lessons in the Animal Industry unit, no related pretests or posttests were administered. The LCTSR pretest was completed by 81 students (70.4%), while the posttest was completed by 39 students (33.9%), leading to a pretest-posttest completion rate of 48.1%. The argumentation pretest was completed by 86 students (74.8%), while the posttest was completed by 39 students (33.9%), resulting in a pretest-posttest completion rate of 45.3%. The VOSE pretest was administered to 78 students (67.8%), while the posttest was completed by 37 students (32.2%), which resulted in a 47.4% completion rate. Student responses were removed from analysis in a pairwise fashion so that only gains between pretests and posttests were included in analysis.
A total of 557 students were removed from the study following their initial consent, resulting in a mortality rate of 82.89%. This mortality rate is considerably higher than others that have been reported in previous experimental studies in agricultural education using intact classes (Jurs & Glass, 1971; Thoron, 2010), reducing the generalizability of this study beyond its participants.

**Objective One: Determine the Effects of an SSI-based Instructional Model on Middle and High School Agriculture Student Agriscience Content Knowledge**

Students’ agriscience content knowledge was assessed through pretests and posttests developed by the researcher. Agriscience content knowledge was assessed distally through a 30-item overall agriscience content knowledge assessment that was administered to the students before the intervention began and upon its conclusion, approximately 14 weeks later. Students’ proximal knowledge was also measured, and was done so through 20-item, unit-based pretests and posttests that were administered immediately prior to and following each unit’s instruction.

**Distal Agriscience Content Knowledge**

Overall agriscience content knowledge was assessed through the use of a 30-item multiple choice instrument. Only students with both completed pretests and posttests were included in analysis, resulting in data from 40 students. The mean score of the pretest was 13.78 ($SD = 3.27$), while the posttest mean score was 17.70 ($SD = 13.93$). Pretest and posttest scores were also examined by school level. Table 4-4 displays the mean scores of middle and high school students on the distal agriscience content knowledge assessment. While middle school students had a higher mean score on the pretest than high school students, high school students generated a higher mean score on the posttest than middle school students.
Proximal Agriscience Content Knowledge

Students’ agriscience content knowledge was assessed proximally before and after each unit of instruction, including Food Safety, Economic Impacts, and Environmental Impacts. Each instrument consisted of 20 items. Animal science concepts were not assessed through a pretest or posttest, as no students were exposed to intervention lessons in the Animal Industry unit. Only students completing both pretest and posttest were included in each analysis, resulting in varying numbers of student scores analyzed for each test. Table 4-5 displays mean scores for unit pretests and posttests. Food Safety assessments were collected from 97 students, which resulted in a mean pretest score of 11.24 (SD = 3.02) and a posttest score of 13.43 (SD = 3.04). Economic Impacts assessments were collected from 102 students, resulting in a mean pretest score of 9.76 (SD = 3.06) and a posttest score of 11.40 (SD = 2.82). Ninety-nine students completed pretests and posttests on the Environmental Impacts unit, resulting in a mean pretest score of 7.41 (SD = 2.31) and a mean posttest score of 9.46 (SD = 2.68).

Table 4-6 displays the means on pretests and posttests for middle school and high school students for each unit. Both middle and high school students generated higher mean scores on the food safety pretest than on any other pretest. Additionally, middle and high school students generated higher means on posttests than on pretests for each unit. Middle school student scores resulted in a higher mean pretest score than that of the high school students on the Food Safety unit assessment. With regard to posttest mean scores, middle school students scored higher than high school students on both the Food Safety and Economic Impacts unit assessments.
Objective Two: Determine the Effects of an SSI-based Instructional Model on Middle and High School Agriculture Student Scientific Reasoning Ability

Students’ scientific reasoning ability was measured through an electronic version of the LCTSR, which contains 24 items requiring higher order thinking skills. These items were developed and deemed appropriate to assess formal scientific reasoning. The LCTSR was administered to students before the intervention began and again following the completion of the intervention lessons. Only students with completed pretests and posttests were included in analysis, which resulted in a sample size of 35. Student scores on the pretest resulted in a mean score of 7.23 ($SD = 2.80$) out of a possible 24. Posttest scores resulted in a mean score of 8.77 ($SD = 3.58$).

Analysis to determine differences between the scientific reasoning scores of middle school and high school students was also conducted. Table 4-7 displays mean scores on pretest and posttest LCTSRs of middle and high school students. Both middle school and high school students’ scores resulted in gains of mean scores from pretest to posttest. Middle school students’ scores resulted in a higher mean pretest score ($M = 7.36, SD = 2.74$) than high school students’ ($M = 6.71, SD = 3.20$), but high school students’ posttest scores resulted in a higher mean ($M = 8.86, SD = 5.18$) than middle school students ($M = 8.75, SD = 3.19$).

Objective Three: Determine the Effects of an SSI-based Instructional Model on Middle and High School Agriculture Student Argumentation Skills

Students’ argumentation skills were assessed through the use of a researcher-developed scenario and Sadler & Fowler’s argumentation rubric (2006). Students were asked to respond to the given scenario before intervention lessons began and again following the completion of the intervention. Following Sadler and Fowler’s instructions, scenario responses were evaluated for the number of justifications and the quality of
justification on a five-point scale. Multiple raters were utilized to establish inter-rater consistency.

Students’ mean number of justifications on the pretest scenario was 2.26 ($SD = .95$) (Table 4-8). Pretest justification score was 1.67 ($SD = .85$). The mean number of justifications decreased to 2.21 on the posttest ($SD = .97$), while the mean justification score increased to 2.40 ($SD = .97$).

Justification number and quality were analyzed by school level as well. Middle school students’ ($n = 28$) mean number of justifications on the pretest was 2.07 ($SD = .81$), while high school students’ ($n = 30$) mean number of pretest justifications was 2.43 ($SD = 1.04$) (Table 4-9). Middle school students’ mean justification quality score was 1.79 ($SD = .79$) on the pretest, while high school students’ mean pretest justification quality score was 1.57 ($SD = .90$). On the pretest, middle school students had a lower mean number of justifications, but a higher mean score of justification quality when compared to high school students. On the posttest, middle school students had a mean justification number of 1.86 ($SD = .89$), while high school students had a mean justification number of 2.53 ($SD = .94$). Middle school students’ justification quality scores on the posttest resulted in a mean score of 1.86 ($SD = .80$), while high school posttest scores led to a mean score of 2.90 ($SD = .85$). On the posttest, middle school students offered fewer justifications and had lower justification quality than high school students. When comparing means within groups, middle school students offered fewer justifications from pretest to posttest, but wrote justifications of better quality. High school students offered more justification from pretest to posttest, and wrote justifications of higher quality.
Objective Four: Determine the Effects of an SSI-based Instructional Model on Middle and High School Agriculture Student Views of the NOS

Students’ views of the NOS were assessed through Chen’s VOSE (2006), which was administered before students were exposed to intervention lessons and again following the completion of the intervention. The VOSE can be scored in different fashions based on the intent of the researcher. Because no explicit attempt was made to incorporate NOS instruction into the intervention, student responses were analyzed descriptively rather than through the use of summative scores, which implies that some views are more preferred over others (Chen, 2006). Only student with both pretest and posttest scores were included in analysis, leading to a sample size of 35.

Whether Scientists Accept Multiple Theories to Explain the Same Phenomenon

Items 1A through 1H ask students to consider whether scientists can accept multiple theories to explain the same phenomenon. Items 1A and 1B state that scientists can accept multiple theories, either because they cannot identify the correct one yet (1A) or because they might both be correct by providing explanations from different perspectives (1B). Items 1C through 1H state that scientists cannot accept multiple theories simultaneously because: (1C) scientists accept more familiar theories over less familiar ones; (1D) scientists accept simpler theories over more complex ones; (1E) scientists are influenced by the academic status of people proposing the theories; (1F) scientists accept more traditional, conservative theories which deviate less from the core scientific theory; (1G) scientists use intuition to make judgments; and (1H) there is only one truth, so no theory will be accepted before one is determined to be best.

Figure 4-1 displays students’ pretest and posttest responses related to whether they agree or disagree with comments that agree with the notion that scientists can
accept multiple theories simultaneously, regardless of the reason. While trends between the levels of responses remained fairly consistent between the pretest and posttest, more students ($n = 22$) were uncertain about the agreement statements on the posttest than on the pretest ($n = 19$). Further, fewer students strongly disagreed with the statements following the intervention ($n = 9$) than before the intervention ($n = 12$).

Figure 4-2 displays students’ pretest and posttest responses related to whether they agree or disagree with comments that disagree with the notion that scientists can accept multiple theories simultaneously, regardless of the reason. Before the intervention, the majority of student responses displayed uncertainty about whether they agreed or disagreed with statements reflecting disagreement to the notion that scientists can accept multiple theories simultaneously to explain a phenomenon ($n = 75$). Following the intervention, fewer students expressed uncertainty and an increased number of students expressed disagreement to these statements ($n = 62$).

Figure 4-3 displays student pretest and posttest responses to Item 1A, which claims that scientists can accept multiple theories when they cannot identify which is more correct. While pretest responses indicated that the majority of students agreed with the statement ($n = 15$), posttest responses indicated that the majority of students were uncertain about the statement ($n = 12$), with almost equal numbers of students responding with agreement ($n = 11$) and disagreement ($n = 12$).

Figure 4-4 displays student pretest and posttest responses to Item 1B, which claims that scientists can accept multiple theories because they may provide explanations from multiple perspectives, indicating that neither is right or wrong. While
trends between pretest and posttest responses were similar, students’ posttest responses indicated more agreement ($n = 16$) than responses on the pretest ($n = 13$).

Figure 4-5 displays student responses on Item 1C, which states that scientists cannot accept multiple theories simultaneously to explain the same phenomenon because scientists accept the theory they are more familiar with. Responses indicated a decreased frequency of students with uncertain feelings toward the statement (pretest, $n = 13$, posttest, $n = 9$), and an increased number of students disagreeing with the statement (pretest, $n = 14$, posttest, $n = 18$).

Figure 4-6 displays students’ pretest and posttest responses on Item 1D, which states that scientists cannot accept multiple theories simultaneously because they accept simpler theories in order to avoid complex theories. Results indicate that before the intervention, more students were uncertain about their level of agreement with this statement ($n = 11$), whereas after the intervention, more students disagreed with the statement ($n = 25$).

Figure 4-7 displays students’ responses on Item 1E, which states that scientists cannot accept multiple theories at the same time to explain a phenomenon because the academic status of the individuals proposing each theory will influence scientists’ acceptance of the theory. Pretest results indicate that the majority of students were uncertain about their level of agreement with this statement ($n = 19$), while posttest responses display more students disagreeing with the statement ($n = 18$).

Figure 4-8 offers students’ pretest and posttest responses to Item 1F, which states that scientists cannot accept multiple theories simultaneously because scientists accept new theories which deviate less from core scientific theory. On the pretest, more
students offered strong responses of disagreement \((n = 10)\), while on the posttest, more students offered more mild responses of disagreement \((n = 13)\), as well as responses of uncertainty \((n = 11)\). Additionally, fewer students offered responses of agreement on the posttest \((n = 4)\) than on the pretest \((n = 7)\).

Figure 4-9 displays students’ responses to Item 1G, which states that scientists cannot accept multiple theories simultaneously to explain the same phenomenon because scientists use intuition to make judgments between theories. While trends were similar between the pretest and posttest responses, no students strongly agreed with the statement on the posttest.

Figure 4-10 displays students’ pretest and posttest responses for Item 1H, which states that scientists cannot accept multiple theories at the same time to explain a phenomenon because there is only one truth and scientists will not accept any theory before determining which is best. More students disagreed with the statement before the intervention \((n = 17)\), while student responses after the intervention reflected a more normal distribution, with increased numbers of uncertain \((n = 11)\) and agree responses \((n = 7)\).

**Whether Scientific Investigations are Influenced by Socio-cultural Values**

Items 2A through 2D respond to the statement, “scientific investigations are influenced by socio-cultural values”. Both 2A and 2B respond in agreement, with the reasoning that socio-cultural values influence the direction and topics of scientific investigation (2A) and that scientists are influenced by socio-cultural values (2B). Items 2C and 2D respond in disagreement, with the reasoning that scientists will remain value-free when conducting research (2C) or because science requires objectivity (2D). Figure 4-11 displays the level of agreement students had when responding to
statements that responded in agreement to the notion that scientific investigations are influenced by socio-cultural values. While the responses on the pretest and posttest follow very similar trends, more respondents disagreed with the statements on the posttest \((n = 20)\) while fewer responded with uncertainty \((n = 25)\) than on the pretest \((n = 30)\).

Figure 4-12 displays students’ responses to Items 2C and 2D, which respond with disagreement to the statement regarding the influence of socio-cultural values on scientific investigations. As with the agreement statements, trends of responses on pretests and posttests were similar. However, posttest responses revealed a slight increase in uncertainty \((n = 26)\).

Figure 4-13 depicts student responses on Item 2A, which states that socio-cultural values influence the direction and topics of scientific investigation. While both response sets resulted in normal distributions, more students agreed with the statement \((n = 9)\) and fewer were uncertain on the posttest \((n = 13)\) than on the pretest \((n = 15)\).

Figure 4-14 reports student responses on pretests and posttests for Item 2B, which states that scientific investigations are influenced by socio-cultural values because the scientists themselves are influenced by these values. While more students agreed with the statement on the pretest \((n = 11)\), posttest scores indicated that more students disagreed with the statement after the intervention \((n = 13)\).

Responses to Item 2C, which states that scientific investigations are not influenced by socio-cultural values because scientists are trained to remain value-free when carrying out research, are displayed in Figure 4-15. While students’ responses in each category had little variability on both the pretest and posttest, more students felt
uncertain about their level of agreement with the statement on the posttest \((n = 10)\) than on the pretest \((n = 6)\).

Figure 4-16 displays students’ pretest and posttest responses to Item 2D, which states that scientific investigations are not influenced by socio-cultural values because science requires objectivity. Both response sets represent normal distributions, and little change was seen in the frequency of responses between the pretest and posttest.

**Whether Scientists Use Their Imaginations**

Items 3A through 3E respond to the question, “when scientists are conducting scientific research, will they use their imagination?” Items 3A and 3B respond in agreement, offering that imagination is the source of innovation (3A) and that scientists use their imagination in research (3B). Items 3C through 3E responded in disagreement, offering that imagination and scientific principles are not consistent (3C), imagination may aid scientists in trying to prove a point at all costs (3D), and that imagination lacks reliability (3E). Figure 4-17 displays student responses to those statements that respond in agreement, regardless of the reason. Student responses were more varied on the posttest than on the pretest, reflecting a more normal distribution following the intervention.

Figure 4-18 displays student responses to Items 3C through 3E, which each disagree with the notion that scientists use their imaginations when conducting research. More students offered responses of uncertainty on the pretest \((n = 32)\), while more students offered strong responses at either end of the spectrum on the posttest (strongly disagree, \(n = 11\), strongly agree, \(n = 19\)).

Figure 4-19 displays student responses on Item 3A, which states that scientists utilize their imaginations, as imagination is the main source of innovation. Fewer
students reported feelings of uncertainty \((n = 10)\) and more students strongly agreed with the statement \((n = 6)\) on the posttest than on the pretest \((n = 11, 6\) respectively).

Responses to Item 3B, which states that scientists use their imagination in scientific research, are displayed in Figure 4-20. While trends between the two response sets were similar, more students strongly agreed with the statement on the posttest \((n = 4)\) than on the pretest \((n = 2)\).

Figure 4-21 displays student pretest and posttest responses to Item 3C, which states that scientists do not use their imaginations when conducting research because imagination is not consistent with the logical principles of science. Frequency of responses remained fairly consistent between the pretest and posttest.

Figure 4-22 displays students’ pretest and posttest responses to Item 3D, which states that scientists do not use their imaginations when conducting research because imagination may become a means for a scientists to prove a point at all costs. Fewer students were uncertain about their feelings toward this statement on the posttest \((n = 6)\), and posttest results yielded more students responding in disagreement \((n = 16)\).

Responses to Item 3E, which states that scientists do not use their imaginations when conducting scientific research because imagination lacks reliability, are displayed in Figure 4-23. Fewer students were uncertain about their level of agreement toward this statement on the posttest \((n = 11)\), and more students strongly agreed with the statement following the intervention \((n = 9)\).

**Whether Scientific Theories are Tentative**

Items 4-A, 4-B, and 4-C examined students’ views regarding the tentative nature of scientific theories. Each item responds to the statement, “even if the scientific investigations are carried out correctly, the theory proposed can still be disproved in the
future”. Item 4-A reflects a revolutionary position, stating that theories undergo drastic change. Figure 4-24 displays student responses on the pretest and posttest for this item. Students held relatively similar views regarding this revolutionary position of the tentativeness of scientific theories, with the majority of students either disagreeing (pretest, n = 13, posttest, n = 15) or being uncertain (pretest, n = 11, posttest, n = 11) with this viewpoint on both the pretest and the posttest.

Item 4-B reflects a cumulative position, stating that theories are altered through a gradual, cumulative process. Figure 4-25 displays student responses on the pretest and posttest for this item. While the majority of students reported that they agreed with this cumulative position on the pretest (n = 20), posttest results indicate that more students were uncertain of their viewpoints on this position (n = 17).

Item 4-C reflects an evolutionary position, stating that the theory is not replaced or disproved, but rather evolves slowly as information is gathered. Figure 4-26 displays differences between students’ responses to this item. Both responses on both the pretest and posttest reveal that the majority of students are either uncertain or agree with this position.

**Whether Scientists’ Observations are Influenced by Personal Beliefs**

Items 5A through 5E examine students’ level of agreement responding to the statement, “scientists’ observations are influenced by personal beliefs; therefore, scientists may not make the same observations for the same experiment.” Item 5A states that observations will be different because different beliefs influence observation. Items 5B through 5E state that observations will be the same, for different reasons: (5B) scientists in the same field hold similar beliefs; (5C) scientists are trained to abandon their personal values in order to conduct objective observations; (5D) observations are
truth and cannot be observed differently by different people; and (5E) scientists use
different methods to verify results and improve objectivity, although subjectivity can
never be completely avoided.

Figure 4-27 examines student responses to Item 5A, which states that
observations between scientists are different because different beliefs influence
observations. Students’ responses remained unchanged between the pretest and
posttest.

Students’ responses to Item 5B, stating that scientists’ observations are the same
because scientists in the same field hold similar ideas, are displayed in Figure 4-28.
While both response sets follow a normal distribution, student responses on the posttest
depict increased feelings of disagreement with the statement (n = 17).

Figure 4-29 displays students’ pretest and posttest responses to Item 5C, which
states that scientists’ observations are the same because training enables scientists to
abandon personal values in the interest of objectivity. Posttest results indicate less
feelings of uncertainty (n = 8) and increased feelings of agreement (n = 15) toward the
statement.

Responses to Item 5D, which states that scientists’ observations are the same
because observations are fact and therefore cannot be observed differently, are
displayed in Figure 4-30. Differences between pretest and posttest scores indicate a
shift toward less strong feelings of disagreement with the statement.

Figure 4-31 depicts students’ pretest and posttest responses to Item 5E, which
states that the observations made by scientists are the same because scientists reduce
their subjectivity by utilizing methods to verify observations. While the majority of
students were uncertain about their level of agreement on the pretest (n = 14) and very few offered feelings of disagreement (n = 4), students’ responses on the posttest were split evenly between agreement and disagreement. Fewer students felt uncertain about their level of agreement on the posttest (n = 6) than on the pretest.

**Whether Scientists Follow a Scientific Method**

Items 6A through 6F respond to the statement, “most scientists follow the universal scientific method, step-by-step, to do their research”. Item 6A states that scientists follow the scientific method because it ensures valid, clear, logical, and accurate results. Item 6B states that scientists utilize the scientific method because it is logical. Item 6C states that while the scientific method is useful in most instances, scientists may need to invent new methods to collect appropriate results. Item 6D states that there is no universal scientific method, and so scientists utilize any methods to obtain results. Item 6E states that a lack of one fixed scientific method leads to the accidental discovery of knowledge. Lastly, Item 6F states that while results can be obtained a number of different ways, scientists utilize the scientific method to verify them.

Figure 4-32 displays student responses to Item 6A, which states that scientists follow the scientific method because it ensures clear, valid, logical, and accurate results. Frequencies in each response category remained virtually unchanged from pretest to posttest.

Student responses to Item 6B, which states that scientists use the scientific method because it is a logical procedure, are displayed in Figure 4-33. While trends between pretest and posttest response sets remained similar, more students disagreed
with the statement on the pretest \((n = 9)\) than on the posttest \((n = 5)\), while more students agreed with the statement on the posttest \((n = 24)\) than on the pretest \((n = 21)\).

Figure 4-34 displays students’ pretest and posttest responses to Item 6C, which states that while the scientific method is useful in most instances, scientists may invent new methods to ensure appropriate results. Fewer students were uncertain about their level of agreement with the statement on the posttest \((n = 9)\); this led to slightly higher frequencies of both students who agreed and disagreed with the statement.

Figure 4-35 displays students’ pretest and posttest responses to Item 6D, which states that there is no scientific method, and scientists utilize any methods necessary to obtain results. While a high number of students were uncertain about their level of agreement with this statement on the pretest \((n = 11)\), fewer students were uncertain following the intervention \((n = 8)\). Further, the difference between the number of students who disagreed with the statement and the number who agreed with the statement was smaller on the pretest than on the posttest; more students disagreed and fewer student agreed on the posttest than on the pretest.

Figure 4-36 displays students’ pretest and posttest responses to Item 6E, which states that there is no fixed scientific method and that scientific knowledge can be accidentally discovered. Fewer students were uncertain regarding their level of agreement with this statement on the posttest \((n = 7)\) than on the pretest \((n = 12)\), and more students strongly disagreed with the statement following the intervention \((n = 9)\).

Finally, students’ responses to Item 6F, which states that regardless of how results are obtained, scientists utilize the scientific method to verify them, are displayed in Figure 4-37. While the majority of students expressed either uncertainty \((n = 14)\) or
agreement ($n = 16$) to this statement on the pretest, posttest responses saw a growing number of students expressing disagreement ($n = 9$) and a reduction in the number of students expressing uncertainty ($n = 7$).

**Tests of Hypotheses**

The dependent variables in this study were students’ agriscience content knowledge, scientific reasoning ability, argumentation skills, and views of the NOS. Each of these was measured through interval data. The study’s independent variable was the teaching method utilized in Agriscience Foundations classes. Both presage variables and context variables were considered antecedent variables and were, therefore, treated as static attributes.

Hypotheses related to the statistical significance of possible effects of an SSI-based instructional model on students’ agriscience content knowledge, scientific reasoning ability, argumentation skills, and views of the NOS were formulated. All hypotheses were non-directional. Decisions to retain or reject the null hypotheses at the .05 level were made according to the results of paired-samples $t$ tests, which were conducted to analyze the data.

**Hypotheses Related to Agriscience Content Knowledge Attainment**

$H_0^1$ – There is no significant difference between the agriscience content knowledge of secondary agriculture students before and after experiencing SSI-based instruction.

Student agriscience content knowledge was measured distally through an overall agriscience content assessment before the intervention began and again following the intervention’s conclusion. Gains in score from pretest to posttest were measured to determine the content knowledge attained by students during the time of the intervention. The mean pretest score was $13.78 (SD = 3.27)$, while the posttest mean
score was 17.70 ($SD = 13.93$). While the overall mean posttest score was higher than the mean pretest score, results from a paired-samples $t$ test found that this difference was not significant, $t(39) = -1.80, p > .05$ (Table 4-10).

Paired-sample $t$ tests were also calculated separately for middle school ($n = 28$) and high school ($n = 12$) students. Results indicated that there was no significant difference between pretest ($M = 14.07, SD = 3.40$) and posttest ($M = 15.25, SD = 4.21$) scores of middle school students, $t(27) = -1.28, p > .05$, and no significant difference between the pretest ($M = 13.08, SD = 2.97$) and posttest ($M = 23.42, SD = 24.35$) scores of high school students, $t(11) = -1.53, p > .05$.

Proximal measurement was conducted through unit-based pretests and posttests that were administered immediately before and following the Food Safety, Economic Impacts, and Environmental Impacts units. Food Safety assessments were collected from 97 students, which resulted in a mean pretest score of 11.24 ($SD = 3.02$) and a posttest score of 13.43 ($SD = 3.04$). Economic Impacts assessments were collected from 102 students, resulting in a mean pretest score of 9.76 ($SD = 3.06$) and a posttest score of 11.4 ($SD = 2.82$). Ninety-nine students completed pretests and posttests on the Environmental Impacts unit, resulting in a mean pretest score of 7.41 ($SD = 2.31$) and a mean posttest score of 9.46 ($SD = 2.68$). Student gains in each unit were calculated through paired-samples $t$ tests. There was a significant increase in student scores between the pretest and posttest of the Food Safety unit, $t(96) = -6.94, p < .05, d = .72$, Economic Impacts unit, $t(101) = -6.05, p < .05, d = .56$, and Environmental Impacts unit, $t(98) = -7.56, p < .05, d = .82$. 

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Paired-samples \( t \) tests were also calculated separately for middle and high school students on each of the proximal assessments. Analysis of middle school students’ scores resulted in significant gains between pretest and posttest scores on the Food Safety unit assessment, \( t(63) = -5.82, p < .05, d = .82 \), Economic Impacts unit assessment, \( t(72) = -5.86, p < .05, d = .65 \), and Environmental Impacts unit assessment, \( t(66) = -5.64, p < .05, d = .66 \). Analysis of high school scores resulted in significant gains between pretest and posttest scores on each unit assessment as well: (a) Food Safety, \( t(31) = -3.79, p < .05, d = .56 \); (b) Economic Impacts, \( t(28) = -2.09, p < .05, d = .33 \); and (c) Environmental Impacts, \( t(31) = -5.13, p < .05, d = .37 \).

Because each of the proximal assessments resulted in significant gains between posttest and pretest, the null hypotheses of no difference in agriscience content knowledge before and after experiencing SSI-based instruction was rejected. However, students’ lack of a significant gain in overall agriscience content knowledge may imply that confounding variables, such as student maturation, history, or fatigue may affect the impact of SSI-based instruction.

**Hypothesis Related to Scientific Reasoning Skills**

\( H_0 \) – There is no significant difference between the scientific reasoning ability of secondary agriculture students before and after experiencing SSI-based instruction.

Student scientific reasoning skills were measured through the use of the LCTSR, which was administered before and after the intervention. Gains in score from pretest to posttest were measured to determine the scientific reasoning skills developed by students during the time of the intervention. Student scores on the pretest resulted in a mean score of 7.23 (\( SD = 2.80 \)) out of a possible 24. Posttest scores resulted in a mean score of 8.77 (\( SD = 3.58 \)). A paired samples \( t \) test found that the gains between pretest
and posttest scores were statistically significant, \( t(34) = -3.19, p < .05, d = .47 \) (Table 4-11).

Student scores on scientific reasoning pretests and posttests were analyzed by school level as well. Middle school students’ scores resulted in a higher mean pretest score \((M = 7.36, SD = 2.74)\) than high school students’ \((M = 6.71, SD = 3.20)\), but high school students’ posttest scores resulted in a higher mean \((M = 8.86, SD = 5.18)\) than middle school students \((M = 8.75, SD = 3.19)\). Paired-samples \( t \) tests were conducted on both middle and high school students’ scientific reasoning gains. Middle school gains between LCTSR pretests and posttests were statistically significant, \( t(27) = -2.53, p < .05, d = .47 \). High school gains between pretests and posttests were not statistically significant, \( t(6) = -3.03, p > .05 \). Because scientific reasoning score gains were deemed to be statistically significant for all students and for middle school students, the null hypotheses of no difference between students’ scientific reasoning ability before and after treatment was rejected. However, because no statistical significant difference was found between high school students’ scientific reasoning ability pretests and posttests, confounding variables, such as age and teacher, may have impacted the effect SSI-based instruction had on students.

**Hypothesis Related to Argumentation Skills**

\( H_0^3\)– There is no significant difference between the argumentation skills of secondary agriculture students before and after experiencing SSI-based instruction.

Student argumentation skills were measured through the use of a researcher-developed argumentation scenario and Sadler & Fowler’s (2006) argumentation rubric, which was administered before and after the intervention. Both the number of justifications and the quality of those justifications were evaluated. Gains in score from
pretest to posttest were measured to determine argumentation skills developed by students during the time of the intervention. Students’ mean number of justifications on the pretest scenario was 2.26 ($SD = .95$). The mean pretest justification score was 1.67 ($SD = .85$). The mean number of justifications decreased to 2.21 on the posttest ($SD = .97$), while the mean justification score increased to 2.40 ($SD = .97$). A paired-samples $t$ test was calculated to determine the significance of differences between number and quality of justifications on the argumentation pretest and posttest. While the difference between the number of students’ justifications on pretests and posttests was not significant, $t(57) = .29$, $p > .05$, there was a significant increase in students’ justification quality, $t(57) = -4.13$, $p < .05$, $d = .73$ (Table 4-12).

Argumentation skills were also analyzed by school level. Middle school students’ ($n = 28$) mean number of justifications on the pretest was 2.07 ($SD = .81$), while high school students’ ($n = 30$) mean number of pretest justifications was 2.43 ($SD = 1.04$). Middle school students’ mean justification quality score was 1.79 ($SD = .79$) on the pretest, while high school students’ mean pretest justification quality score was 1.57 ($SD = .90$). On the posttest, middle school students had a mean justification number of 1.86 ($SD = .89$), while high school students had a mean justification number of 2.53 ($SD = .94$). Middle school students’ justification quality scores on the posttest resulted in a mean score of 1.86 ($SD = .80$), while high school posttest scores led to a mean score of 2.90 ($SD = .85$). Paired-samples $t$ tests were calculated separately for middle and high school students’ differences in number of justifications and quality of justifications between the pretest and posttest. With regard to number of justifications, there was no significant difference between middle school students’ pretest and posttest scores, $t(27)$
= 1.03, \( p > .05 \), or high school students’ pretest and posttest scores, \( t(29) = -.36, p > .05 \). While there was no significant difference in the quality of middle school students’ justifications between the pretest and posttest, \( t(27) = -.372, p > .05 \), there was a significant difference in the quality of high school students’ justifications between the pretest and posttest, \( t(29) = -5.53, p < .05, d = 2.72 \). Based on the statistically significant gain in the argumentation quality of high school students, and overall, the null hypothesis of no difference in argumentation skills due to the intervention was rejected. However, a lack of significant difference in justification number indicates that certain aspects of argumentation may be impacted by SSI-based instruction than more so others. Further, the lack of a significant difference in middle school students’ argumentation quality may indicate that confounding variables, such as age and teacher, may impact SSI-based instruction’s role in argumentation skill acquisition.

**Hypothesis Related to Views of the NOS**

\[ H_0^4 \] – There is no significant difference between the views of the NOS of secondary agriculture students before and after experiencing SSI-based instruction.

Students’ views of the NOS were measured through the use of Chen’s (2006) VOSE, which was administered before and after the intervention. Frequencies of responses to each item and to each aspect of the NOS were evaluated. Differences in responses from pretest to posttest were measured to determine students’ views of the NOS that changed during the time of the intervention. Students’ responses to the following views of the NOS were evaluated: (a) whether scientists can accept multiple theories simultaneously to explain a phenomenon, (b) whether scientific investigations are influenced by socio-cultural values, (c) whether scientists use their imaginations during scientific research, (d) whether scientific theories are tentative, (e) whether
scientists’ observations are influenced by personal beliefs, and (f) whether scientists follow a universal scientific method.

With regard to whether scientists can accept multiple theories simultaneously to explain a phenomenon, the mean difference between pretest and posttest views was .86, which represents less than one category shift (on a five-point scale from strongly disagree to strongly agree). A paired-samples t test found this difference to be statistically insignificant, \( t(34) = 1.10, p > .05 \) (Table 4-13).

With regard to whether scientific investigations are influenced by socio-cultural values, the mean difference between pretest and posttest views was .29, which represents less than one category shift (on a five-point scale from strongly disagree to strongly agree). A paired-samples t test found this difference to be statistically insignificant, \( t(34) = .55, p > .05 \).

With regard to whether scientists use their imaginations during scientific research, the mean difference between pretest and posttest views was -0.20, which represents less than one category shift (on a five-point scale from strongly disagree to strongly agree). A paired-samples t test found this difference to be statistically insignificant, \( t(34) = -0.27, p > .05 \).

With regard to whether scientific theories are tentative, the mean difference between pretest and posttest views was 0.03, which represents less than one category shift (on a five-point scale from strongly disagree to strongly agree). A paired-samples t test found this difference to be statistically insignificant, \( t(34) = 0.08, p > .05 \).

With regard to whether scientists’ observations are influenced by personal beliefs, the mean difference between pretest and posttest views was 0.74, which represents
less than one category shift (on a five-point scale from strongly disagree to strongly agree). A paired-samples \( t \) test found this difference to be statistically insignificant, \( t(33) = 1.07, p > .05 \).

With regard to whether scientists follow a universal scientific method, the mean difference between pretest and posttest views was 1.46, which represents over one category shift (on a five-point scale from strongly disagree to strongly agree). A paired-samples \( t \) test found this difference to be statistically insignificant, \( t(34) = 1.65, p > .05 \). Because no statically significant differences were found on constructs of views of the NOS between the pretest and posttest, the null hypothesis of no differences in students’ views of the NOS before and after the treatment was retained.

**Summary**

Chapter 4 presented the findings of the study according to the study’s objectives and hypotheses. Objectives included: (a) to determine the effects of an SSI-based instructional model on secondary agriculture student agriscience content knowledge, (b) to determine the effects of an SSI-based instructional model on secondary agriculture student scientific reasoning ability, (c) to determine the effects of an SSI-based instructional model on secondary agriculture student argumentation skills, and (d) to determine the effects of an SSI-based instructional model on secondary agriculture student views of the NOS. The null hypotheses related to each of the objectives included: (a) there is no significant difference between the agriscience content knowledge of secondary agriculture students before and after experiencing SSI-based instruction; (b) there is no significant difference between the scientific reasoning ability of secondary agriculture students before and after experiencing SSI-based instruction; (c) there is no significant difference between the argumentation skills of secondary
agriculture students before and after experiencing SSI-based instruction; and (d) there is no significant difference between the views of the NOS of secondary agriculture students before and after experiencing SSI-based instruction.

Chapter 5 will discuss these findings in detail, providing conclusions, recommendations, and implications related to the above results. Further, Chapter 5 will detail how these findings, in their entirety, can impact student learning in agricultural education, as well as future research in the profession.
Table 4-1. Teacher demographics

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<th>Training Session</th>
<th>School Level</th>
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<th>Level of Experience with EL</th>
<th>Level of Experience with Inquiry-based Instruction</th>
<th>Level of Experience with Problem Solving</th>
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Table 4-2. Student demographics and test completion

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Note: ArgPre = Argumentation Pretest; ArgPost = Argumentation Posttest; AgrPre = Distal Agriscience Content Pretest; AgrPost = Distal Agriscience Content Posttest; SRPre = Scientific Reasoning Pretest; SRPost = Scientific Reasoning Posttest; NosPre = Nature of Science Pretest; NosPost = Nature of Science Posttest; FSPre = Food Safety Pretest; FSPost = Food Safety Posttest; EcPre = Economic Impacts Pretest; EcPost = Economic Impacts Posttest; EnvPre = Environmental Impacts Pretest; EnvPost = Environmental Impacts Posttest.
### Table 4-3. Completion rates for instruments

<table>
<thead>
<tr>
<th>Instrument</th>
<th>n</th>
<th>Response Rate</th>
<th>Pretest-Posttest Completion Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Agriscience Content Pretest</td>
<td>80</td>
<td>69.6%</td>
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</tr>
<tr>
<td>Overall Agriscience Content Posttest</td>
<td>40</td>
<td>34.8%</td>
<td>50.0%</td>
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<tr>
<td>Food Safety Unit Pretest</td>
<td>106</td>
<td>92.2%</td>
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</tr>
<tr>
<td>Food Safety Unit Posttest</td>
<td>98</td>
<td>85.2%</td>
<td>92.5%</td>
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<tr>
<td>Economic Impacts Unit Pretest</td>
<td>109</td>
<td>94.8%</td>
<td>--</td>
</tr>
<tr>
<td>Economic Impacts Unit Posttest</td>
<td>102</td>
<td>88.7%</td>
<td>93.6%</td>
</tr>
<tr>
<td>Environmental Impacts Unit Pretest</td>
<td>108</td>
<td>93.9%</td>
<td>--</td>
</tr>
<tr>
<td>Environmental Impacts Unit Posttest</td>
<td>No</td>
<td>86.1%</td>
<td>91.7%</td>
</tr>
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<td>Animal Industry Unit Pretest</td>
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<tr>
<td>Animal Industry Unit Posttest</td>
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<td>0%</td>
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<td>LCTSR Pretest</td>
<td>81</td>
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<td>LCTSR Posttest</td>
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<td>33.9%</td>
<td>48.1%</td>
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<td>Argumentation Assessment Pretest</td>
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<td>--</td>
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<tr>
<td>Argumentation Assessment Posttest</td>
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<td>45.3%</td>
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<td>VOSE Pretest</td>
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<td>67.8%</td>
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<td>VOSE Posttest</td>
<td>37</td>
<td>32.2%</td>
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### Table 4-4. Mean Pretest and Posttest Scores on Distal Content Knowledge Assessments of Middle and High School Students

<table>
<thead>
<tr>
<th>School Level</th>
<th>Pretest $M$</th>
<th>Pretest $SD$</th>
<th>Posttest $M$</th>
<th>Posttest $SD$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle School</td>
<td>14.07</td>
<td>3.40</td>
<td>15.25</td>
<td>4.21</td>
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<tr>
<td>High School</td>
<td>13.08</td>
<td>2.97</td>
<td>23.42</td>
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### Table 4-5. Mean Pretest and Posttest Scores on Proximal Content Knowledge Assessments

<table>
<thead>
<tr>
<th>Content Knowledge Instrument</th>
<th>Pretest $M$</th>
<th>Pretest $SD$</th>
<th>Posttest $M$</th>
<th>Posttest $SD$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Safety $(n = 97)$</td>
<td>11.24</td>
<td>3.02</td>
<td>13.43</td>
<td>3.04</td>
</tr>
<tr>
<td>Economic Impacts $(n = 102)$</td>
<td>9.76</td>
<td>3.06</td>
<td>11.40</td>
<td>2.82</td>
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<tr>
<td>Environmental Impacts $(n = No)$</td>
<td>7.41</td>
<td>2.31</td>
<td>9.46</td>
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</table>

### Table 4-6. Mean Pretest and Posttest Scores on Proximal Content Knowledge Assessments for Middle and High School

<table>
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<tr>
<th>Content Knowledge Instrument</th>
<th>Pretest $M$</th>
<th>Pretest $SD$</th>
<th>Posttest $M$</th>
<th>Posttest $SD$</th>
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<tbody>
<tr>
<td>Food Safety</td>
<td>11.38</td>
<td>3.41</td>
<td>13.77</td>
<td>3.03</td>
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<td>Economic Impacts</td>
<td>9.67</td>
<td>3.37</td>
<td>11.53</td>
<td>2.80</td>
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<tr>
<td>Environmental Impacts</td>
<td>7.40</td>
<td>2.37</td>
<td>9.06</td>
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Table 4-7. Mean scores on LCTSR pretests and posttests of middle and high school students

<table>
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<tr>
<th>School Level</th>
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<th>Pretest SD</th>
<th>Posttest M</th>
<th>Posttest SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle School (n = 28)</td>
<td>7.36</td>
<td>2.74</td>
<td>8.75</td>
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<td>High School (n = 7)</td>
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Table 4-8. Mean Number and Quality of Justifications on Pretests and Posttests

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<th>Pretest SD</th>
<th>Posttest M</th>
<th>Posttest SD</th>
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<tr>
<td>Justification Number</td>
<td>2.26</td>
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<td>Justification Quality</td>
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Table 4-9. Mean Scores of Middle and High School Students’ Number and Quality of Justifications on Argumentation Pretests and Posttests

<table>
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<th>Posttest M</th>
<th>Posttest SD</th>
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Table 4-10. Analysis of Gains in Agriscience Content Knowledge after Treatment

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<th>d</th>
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<tr>
<td>Overall Agriscience Content Knowledge</td>
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<td>High School Overall Content Knowledge</td>
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<td>Food Safety</td>
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<td>Middle School Food Safety</td>
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<td>High School Food Safety</td>
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Table 4-11. Analysis of Gains in Scientific Reasoning after Treatment

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Table 4-12. Analysis of Gains in Argumentation Skill after Treatment

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<td>Construct</td>
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<td>t</td>
<td>p</td>
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<tr>
<td>---------------------------------------------------------------</td>
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<tr>
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<td>.59</td>
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<tr>
<td>Whether scientists use their imaginations during scientific research</td>
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<td>.79</td>
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<td>Whether scientific theories are tentative</td>
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<td>.94</td>
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<tr>
<td>Whether scientists' observations are influenced by personal beliefs</td>
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<td>1.07</td>
<td>.29</td>
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</tr>
<tr>
<td>Whether scientists follow a universal scientific method</td>
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Figure 4-1. Student pretest and posttest responses on Items 1A and 1B, reflecting agreement to the notion that scientists can accept multiple theories simultaneously to explain a phenomenon.
Figure 4-2. Student pretest and posttest responses on Items 1C through 1H, reflecting disagreement to the notion that scientists can accept multiple theories simultaneously to explain a phenomenon.

Figure 4-3. Student pretest and posttest responses on Item 1A.
Figure 4-4. Student pretest and posttest responses on Item 1B

Figure 4-5. Student pretest and posttest responses on Item 1C
Figure 4-6. Student pretest and posttest responses on Item 1D

Figure 4-7. Student pretest and posttest responses on Item 1E
Figure 4-8. Student pretest and posttest responses on Item 1F

Figure 4-9. Student pretest and posttest responses on Item 1G
Figure 4-10. Student pretest and posttest responses on Item 1H

Figure 4-11. Student pretest and posttest responses on Items 2A and 2B, reflecting agreement to the notion that scientists can accept multiple theories simultaneously to explain a phenomenon
Figure 4-12. Student pretest and posttest responses on Items 2C and D, reflecting disagreement to the notion that scientists can accept multiple theories simultaneously to explain a phenomenon.

Figure 4-13. Student pretest and posttest responses on Item 2A.
Figure 4-14. Student pretest and posttest responses on Item 2B

Figure 4-15. Student pretest and posttest responses on Item 2C
Figure 4-16. Student pretest and posttest responses on Item 2D

Figure 4-17. Student pretest and posttest responses on Items 3A and 3B, reflecting agreement to the notion that scientists use their imagination when conducting research.
Figure 4-18. Student pretest and posttest responses on Items 3C through 3E, reflecting disagreement to the notion that scientists use their imaginations when conducting research.

Figure 4-19. Student pretest and posttest responses on Item 3A.
Figure 4-20. Student pretest and posttest responses on Item 3B

Figure 4-21. Student pretest and posttest responses on Item 3C
Figure 4-22. Student pretest and posttest responses on Item 3D

Figure 4-23. Student pretest and posttest responses on Item 3E
Figure 4-24. Student pretest and posttest responses on Item 4-A, reflecting a revolutionary position to the tentative nature of scientific theories.

Figure 4-25. Student pretest and posttest responses on Item 4-B, reflecting a cumulative position on the tentative nature of scientific theories.
Figure 4-26. Student pretest and posttest responses on Item 4-C, reflecting an evolutionary position on the tentative nature of scientific theories.

Figure 4-27. Student pretest and posttest responses on Item 5A.
Figure 4-28. Student pretest and posttest responses on Item 5B

Figure 4-29. Student pretest and posttest responses on Item 5C
Figure 4-30. Student pretest and posttest responses on Item 5D

Figure 4-31. Student pretest and posttest responses on Item 5E
Figure 4-32. Student pretest and posttest responses on Item 6A

Figure 4-33. Student pretest and posttest responses on Item 6B
Figure 4-34. Student pretest and posttest responses on Item 6C

Figure 4-35. Student pretest and posttest responses on Item 6D
Figure 4-36. Student pretest and posttest responses on Item 6E

Figure 4-37. Student pretest and posttest responses on Item 6F
CHAPTER 5
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The purpose of this study was to determine the effect of a socioscientific issues (SSI)-based instructional model on secondary agriscience students’ agriscience content knowledge, scientific reasoning ability, argumentation skill, and views of the nature of science (NOS). The intervention was a nine-week instructional unit designed according to an SSI-based instructional model.

Chapter 1 explained the study’s purpose and offered justification for determining the effect of an SSI-based instructional model on student learning, including the aforementioned dependent variables. The chapter also offered an overview of the national push for scientific literacy. Further, the provided history and evolving purpose of agricultural education detail the importance of teaching scientific literacy in secondary agricultural education.

Chapter 2 provided the study’s theoretical and conceptual frameworks, as well as highlighted the important research related to the study. Theories guiding this study’s conceptual framework were constructivism, experiential learning, and problem solving, as well as Sadler’s (2011) framework for socioscientific issues based education and Dunkin & Biddle’s (1974) model for the study of classroom teaching. A review of the literature aligning with the study’s conceptual framework focused on teacher, student and contextual aspects that influence SSI-based instruction, the design aspects of SSI-based instruction, and student gains in knowledge, argumentation, interest in science, reasoning skills, views of the NOS, and problem solving ability as a result of SSI-based instruction.
Chapter 3 detailed the methods utilized in this study to address the objectives, including the research design, procedures, treatment, population and sample. Also discussed were the study’s treatment, instrument development and data collection procedures, and methods utilized to analyze data.

Chapter 4 presented findings related to each of the four objectives. Following a full description of the results related to the objectives, justification for retention or rejection of each null hypothesis was also provided.

Chapter 5 offers a summary of the study and provides conclusions stemming from the findings. Additionally, the chapter will present recommendations for future research, preservice and inservice teacher education, and curriculum development.

**Objectives**

Guiding this study were the following objectives and hypotheses:

- To determine the effects of an SSI-based instructional model on middle and high school agriculture student agriscience content knowledge.
- To determine the effects of an SSI-based instructional model on middle and high school agriculture student scientific reasoning ability.
- To determine the effects of an SSI-based instructional model on middle and high school agriculture student argumentation skills.
- To determine the effects of an SSI-based instructional model on middle and high school agriculture student views of the NOS.

**Null Hypotheses**

The following null hypotheses were made to guide data analysis:

$H_0^1$ – There is no significant difference between the agriscience content knowledge of secondary agriculture students before and after experiencing SSI-based instruction.
H₀² – There is no significant difference between the scientific reasoning ability of secondary agriculture students before and after experiencing SSI-based instruction.

H₀³ – There is no significant difference between the argumentation skills of secondary agriculture students before and after experiencing SSI-based instruction.

H₀⁴ – There is no significant difference between the views of the NOS of secondary agriculture students before and after experiencing SSI-based instruction.

**Methods**

This study utilized a pre-experimental, single group pretest-posttest design (Campbell & Stanley, 1963). Dependent variables included secondary agriscience students' distal and proximal agriscience content knowledge, scientific reasoning ability, argumentation skills, and views of the NOS.

The study's population was Florida secondary agriscience students. The sampling frame was made up of students in classes of a convenience sample of Florida agriscience teachers. In order to be eligible to participate, teachers had to be teaching at least one Agriscience Foundations class during the 2011-2012 year at either the middle or high school level. Based on Hays' (1973) formula, student sample size was calculated at 60. Because of mortality rates of up to 50% in similar studies (Thoron, 2010), the sample size was doubled to 120. An estimated number of 12 students per class led to a teacher sample size of 10.

Teachers were recruited through convenience sampling methods. Those teachers participating in the Florida Association of Agricultural Educators Summer Conference and regional FFA Chapter Officer Leadership Conferences were invited to attend training sessions featuring the purpose and procedures of the study. The teachers attending the summer conference were offered an in-person training session,
while those attending the leadership conferences attended one of four online training sessions.

The intervention for this study consisted of one nine-week segment of lessons which taught agriscience content through the SSI context of cultured meat. The nine-week segment was broken down into five instructional units, each examining the SSI from a different perspective: (a) food safety, (b) economic impacts, (c) environmental impacts, (d) the animal industry, and (e) introduction of cultured meat. However, students were exposed to all lessons from the food safety, economic impacts, and environmental impacts units, and three of the introduction of cultured meat lessons.

All instructional plans were developed to align with recommended practices of experiential learning (Kolb, 1984), SSI-based instruction (Sadler, 2011), and inquiry-based instruction (NRC, 2000). All lessons were evaluated for content validity by a panel of experts in agricultural education, experiential learning, inquiry-based instruction, and SSI-based instruction.

Treatment fidelity was to be established through the analysis of a random selection of recordings taken from recorded class sessions. Teachers were provided with audio recorders in order to supply the research with recordings of the lessons. However, after weekly reminders in both electronic format and via telephone contacts, teachers failed to consistently record their classes. Therefore, recordings could not be utilized to ensure fidelity of treatment. Informal conversations with teachers during routine contacts and the production of student work required by the lessons implied that teachers followed lesson plans as designed.
Researcher-developed instruments were utilized to evaluate students’ proximal and distal agriscience content knowledge. Because no students were exposed to lessons from the Animal Industry unit, pretests and posttests aligning with this unit were omitted from the study’s analysis. The students were assessed using pretests and posttests, which were identical. Students did not receive feedback on their performance on the pretests before taking the posttests. Content and face validity were established through an expert panel. A pilot test was conducted utilizing 15 University of Florida juniors in agricultural education to establish reliability.

Students’ scientific reasoning ability was measured before and after the intervention through the use of Lawson’s Classroom Test of Scientific Reasoning (LCTSR) (Lawson, 1978, as supplied in Thoron, 2010). Validity was established for the original version of the LCTSR (Lawson, 1978) through review of an expert panel, who established that the test items require students to utilize formal reasoning skills. During the development of the instrument, a Cronbach’s alpha coefficient of .86 was calculated to establish reliability. Because the instrument was designed for post-secondary students, the developer also established reliability for grade levels 8, 9, and 10 through a Kuder-Richardson 20 calculation, which was reported as .78 (Lawson, 1978).

Students’ argumentation skills were evaluated through the use of a researcher-developed scenario and Sadler & Folwer’s (2006) Argumentation Quality Rubric before and after the intervention. Reliability of the rubric was established by Sadler & Fowler (2006) through the use of multiple scorers. Face and content validity of the scenarios were established through review by an expert panel. Inter-rater reliability of response scores in this study was calculated through the use of multiple scorers.
Views of the NOS were assessed using the Views on Science and Education Questionnaire (VOSE) (Chen, 2006). Content validity was established for the assessment’s original version through the use of two separate expert panels and interviews with students to verify item clarity. Based on Chen’s (2006) recommendations, the researcher established face and content validity through a panel of experts. Test-retest reliability was established by the developer with a coefficient of .82. Because of the empirical nature of the instrument, the establishment of internal consistency reliability was not appropriate (Chen, 2006).

Data were analyzed through SPSS version 20. Data corresponding to each objective were analyzed through the use of dependent samples t tests to determine whether null hypotheses were retained or rejected (Agresti & Findlay, 2009). Only students with completed pretests and posttests were included in each analysis.

**Summary of Findings**

Findings are summarized following the study’s objectives and hypotheses. While 672 students originally consented to participate in the study, teacher mortality led to a final overall number of 115. Because some teachers failed to return each assessment, completion rates varied for each objective.

**Objective One**

Objective One sought to determine the effects of an SSI-based instructional model on middle and high school agriculture student agriscience content knowledge, both through an overall assessment and three unit-based assessments. Forty students with completed pretests and posttests were included in analysis of the distal assessment. The mean score of the pretest was 13.78 ($SD = 3.27$), while the posttest mean score was 17.70 ($SD = 13.93$). Pretest and posttest scores were also examined by school
level. Middle school students had a mean pretest score of 14.07 ($SD = 3.40$), while their mean posttest score was 15.25 ($SD = 4.21$). High school students had a lower mean pretest score (13.08, $SD = 2.97$) than middle school students, but had a higher posttest score (23.42, $SD = 24.35$) than middle school students.

Ninety-seven students completed the Food Safety unit assessment. The mean pretest score was 11.24 ($SD = 3.02$), while the mean posttest score increased to 13.43 ($SD = 3.04$). Pretest and posttest scores examined by school level found that both middle school students' (13.77, $SD = 3.03$) and high school students' (12.79, $SD = 3.02$) posttest scores were higher than their pretest scores (middle school = 11.38, $SD = 2.81$, high school = 10.97, $SD = 3.41$). Middle school students had higher mean scores on both the pretest and posttest assessments of the Food Safety unit.

The Economic Impacts unit assessments were administered to 102 students. The mean pretest score was 9.76 ($SD = 3.06$), while the mean posttest score increased to 11.40 ($SD = 2.82$). Assessments were also analyzed by school level. Middle school students' mean pretest score was 9.76 ($SD = 2.94$), while their mean posttest score increased to 11.53 ($SD = 2.80$). High school students' mean pretest score was higher than that of middle school students at 10.00 ($SD = 3.37$). Their mean posttest score increased from their pretest score to 11.07 ($SD = 2.87$), but this posttest score was lower than that of middle school students’.

Ninety-nine students completed the Environmental Impacts unit pretests and posttests. The mean pretest score was 7.41 ($SD = 2.31$), while the mean posttest score increased to 9.46 ($SD = 2.68$). School level analysis indicated that middle school students' mean pretest score was 7.40 ($SD = 2.37$), while their posttest score increased
to 9.06 ($SD = 2.62$). High school students’ mean pretest score was 7.44 ($SD = 2.21$), while their mean posttest score increased to 10.31 ($SD = 2.66$). High school students scored higher than middle school students on both the Environmental Impacts pretest and posttest.

Pretests and posttests indicated that all students increased agriscience content knowledge during the intervention both overall and on each of the individual units. Further, analysis by school level indicated that both middle school and high school students experienced gains in agriscience content knowledge during the SSI-based instructional unit. High school students experienced greater gains than middle school students on the overall test, while middle school students experienced greater gains on the Economic Impacts test.

**Objective Two**

The second objective sought to determine the effects of an SSI-based instructional model on middle and high school agriculture students’ scientific reasoning ability. Thirty-five students completed the pretest and posttest, and were included in the analysis. Student scores on the pretest resulted in a mean score of 7.23 ($SD = 2.80$) out of a possible 24. Posttest scores increased to a mean score of 8.77 ($SD = 3.58$).

Student scores were also analyzed by school level. Middle school students’ scores resulted in a mean pretest score of 7.36 ($SD = 2.74$), while their mean posttest score increased to 8.75 ($SD = 3.19$). High school students had a lower pretest score (6.71, $SD = 3.20$) than middle school students, but finished with a higher mean posttest score (8.86, $SD = 5.18$) than the middle school students.

Overall, students experienced an increase in scientific reasoning ability following the intervention. When examined by school level, both middle school and high school
students experienced an increase in scientific reasoning ability, although the increase of high school students’ scores was greater than that experienced by middle school students.

**Objective Three**

The third objective sought to determine the effects of an SSI-based instructional model on middle and high school agriculture students’ argumentation skills. Fifty-eight students completed the pretest and posttest, and were therefore included in the analysis. Students’ mean number of justifications on the pretest scenario was 2.26 \( (SD = 0.95) \), while the mean number of justifications on the posttest scenario decreased to 2.21 \( (SD = 0.97) \). Pretest justification quality had a pretest mean score of 1.67 \( (SD = 0.85) \), which increased to 2.40 \( (SD = 0.97) \) on the posttest.

When analyzed by school level, middle school students’ pretest mean number of justifications was 2.07 \( (SD = 0.81) \), while their posttest mean number of justifications decreased to 1.86 \( (SD = 0.89) \). High school students’ pretest mean number of justifications was 2.43 \( (SD = 1.04) \), while their posttest mean number of justifications increased to 2.53 \( (SD = 0.94) \). Middle school students’ pretest mean justification quality score was 1.79 \( (SD = 0.90) \), while their score increased to 1.86 \( (SD = 0.80) \) on the posttest. High school students’ pretest mean justification quality score was 2.53 \( (SD = 0.94) \), while their score increased to 2.90 \( (SD = 0.85) \). Middle school students had a lower number of argument justifications and lower quality arguments on both the pretest and posttest than high school students, and their number of justifications decreased from pretest to posttest. High school students’ mean number of justifications increased from pretest to posttest. Both middle school and high school students experienced an increase in argument justification quality during the intervention.
Objective Four

The fourth objective sought to determine the effects of an SSI-based instructional model on middle and high school agriculture students’ views of the NOS. The pretests and posttests of 35 students were collected and included in analysis.

The first viewpoint asked students to consider whether scientists can accept multiple theories to explain the same phenomenon. Student responses reflected an increased frequency of uncertain feelings when considering the following: (a) whether scientists accept multiple theories because they cannot identify which is more correct, (b) whether scientists accept new theories which deviate less from core scientific theory, and (c) whether there is only one truth and scientists will not accept any theory before determining which is best. Student responses reflected a decreased feeling of uncertainty when considering the following: (a) whether scientists accept the theory they are more familiar with instead of accepting multiple theories, (b) whether scientists accept simpler theories in order to avoid more complex theories, and (c) whether the academic status of the individuals proposing each theory will influence acceptance of a theory. Student responses reflected an increased frequency of agreement when considering the following: (a) whether scientists accept multiple theories because theories can provide explanations from multiple perspectives, and (b) whether there is only one truth and scientists will not accept any theory before determining which is best. Student responses reflected an increase in frequency of feelings of disagreement when considering the following: (a) whether scientists accept simpler theories in order to avoid more complex theories, (b) whether scientists accept the theory they are more familiar with instead of accepting multiple theories, and (c) whether the academic status of the individuals proposing each theory will influence scientists’ acceptance of a theory.
The second viewpoint asked students to consider whether scientific investigations are influenced by socio-cultural values. Student responses reflected an increased frequency of uncertain feelings when considering whether scientists are trained to remain value-free when conducting research. Student responses reflected a decreased feeling of uncertainty when considering whether socio-cultural values influence the direction and topics of scientific investigation. Student responses reflected an increased frequency of agreement when considering whether socio-cultural values influence the direction and topics of scientific investigation. Student responses reflected an increase in frequency of feelings of disagreement when considering whether scientific investigations are influenced by socio-cultural values.

The third set of items asked students to consider whether scientists use their imaginations when conducting scientific research. Student responses reflected a decreased feeling of uncertainty when considering the following: (a) whether scientists utilize their imaginations, as imagination is the main source of innovation; (b) whether scientists do not use their imaginations because imagination may become a means for a scientist to prove a point at all costs; and (c) whether imagination lacks reliability. Student responses reflected an increased frequency of agreement when considering the following: (a) whether scientists utilize their imaginations, as imagination is the main source of innovation; (b) whether scientists use their imaginations in scientific research, and (c) whether imagination lacks reliability. Student responses reflected an increase in frequency of feelings of disagreement when considering whether scientists do not use their imaginations when conducting research because imagination may become a means for scientists to prove a point at all costs.
The fourth set of items asked students to consider the tentative nature of scientific theories. Student responses reflected an increased frequency of uncertain feelings when considering whether theories are altered through a gradual, cumulative process. Student responses reflected a decreased feeling of uncertainty when considering whether theory evolves slowly as information of gathered.

The fifth set of items asked students to consider whether scientists’ observations are influenced by personal beliefs. Student responses reflected a decreased feeling of uncertainty when considering the following: (a) whether scientists’ observations are the same because training enables scientists to abandon personal values in the interest of objectivity, and (b) whether scientists reduce their subjectivity by utilizing methods to verify observations. Student responses reflected an increased frequency of agreement when considering whether scientists’ observations are the same because training enables scientists to abandon personal values in the interest of objectivity. Student responses reflected an increase in frequency of feelings of disagreement when considering whether scientists’ observations are the same because scientists in the same field hold similar ideas.

The final group of items asked students to consider whether most researchers follow a universal scientific method, step-by-step, to do their research. Student responses reflected a decreased feeling of uncertainty when considering the following: (a) whether scientists may invent new methods to ensure appropriate results, (b) whether scientists utilize any methods necessary to obtain results, (c) whether there is no scientific method and scientific knowledge can be accidentally discovered, and (d) whether scientists utilize the scientific method to verify results, regardless of how they
are obtained. Student responses reflected an increased frequency of agreement when considering whether scientists use the scientific method because it is a logical procedure. Student responses reflected an increase in frequency of feelings of disagreement when considering the following: (a) whether scientists utilize any methods necessary to obtain results; (b) whether there is no scientific method and scientific knowledge can be accidentally discovered; and (c) scientists utilize the scientific method to verify results, regardless of how they are obtained.

Null Hypothesis One

The study’s first null hypothesis was that there is no significant difference between the agriscience content knowledge of secondary agriculture students before and after experiencing SSI-based instruction. Differences between mean pretest and posttest scores were analyzed for distal and proximal assessments, as well as separately for middle and high school students. On the distal assessment, the mean pretest score was 13.78 ($SD = 3.27$), while the posttest mean score was 17.70 ($SD = 13.93$). Results from a paired-samples $t$ test found that this increase in score from pretest to posttest was not significant, $t(39) = -1.80, p > .05$.

Examination of distal assessment scores for middle and high school students found that the middle school mean pretest score was 14.07 ($SD = 3.40$), while the posttest score increased to 15.25 ($SD = 4.21$). Analysis via a paired-samples $t$ test did not find this increase in score from pretest to posttest to be significant, $t(27) = -1.28, p > .05$. The mean pretest score of high school students was 13.08 ($SD = 2.97$), while the mean posttest score increased to 23.42 ($SD = 24.35$). A paired-samples $t$ test did not find this increase in score to be statistically significant, $t(11) = -1.53, p > .05$. 
Students’ responses on the Food Safety unit assessment resulted in a mean pretest score of 11.24 ($SD = 3.02$), while the mean posttest score rose to 13.43 ($SD = 3.04$). A paired-samples $t$ test found this increase in score from pretest to be significant with a medium effect size, $t(96) = -6.94$, $p < .05$, $d = 0.72$. The mean pretest score of middle school students was 11.38 ($SD = 2.81$), while their mean posttest score was 13.77 ($SD = 3.03$). A paired-samples $t$ test found this increase in score to be statistically significant with a large effect size, $t(63) = -5.82$, $p < .05$, $d = 0.82$. Responses of high school students yielded a mean pretest score of 10.97 ($SD = 3.41$) and a mean posttest score of 12.79 ($SD = 3.02$). A paired-samples $t$ test found this increase to be statistically significant with a medium effect size, $t(31) = -3.79$, $p < .05$, $d = 0.56$.

Students’ responses on the Economic Impacts unit assessment yielded a mean pretest score of 9.76 ($SD = 3.06$) and a mean posttest score of 11.40 ($SD = 2.82$). Analysis via a paired-samples $t$ test found this increase in score to be statistically significant with a medium effect size, $t(101) = -6.05$, $p < .05$, $d = 0.56$. Middle school students’ scores led to a mean pretest score of 9.67 ($SD = 2.94$) and a mean posttest score of 11.53 ($SD = 2.80$). This increase in score between pretest and posttest was found to be statistically significant with a medium effect size through a paired-samples $t$ test, $(72) = -5.86$, $p < .05$, $d = 0.65$. Scores of high school students yielded a mean pretest score of 10.00 ($SD = 3.37$) and a mean posttest score of 11.07 ($SD = 2.87$). A paired-samples $t$ test found this gain to be statistically significant with a low effect size, $t(28) = -2.09$, $p < .05$, $d = 0.33$.

Responses on the Environmental Impacts unit assessment resulted in a mean pretest score of 7.41 ($SD = 2.31$) and a mean posttest score of 9.46 ($SD = 2.68$). A
paired-samples $t$ test found this growth to be statistically significant with a large effect size, $t(98) = -7.56, p < .05, d = 0.82$. Middle school responses yielded a mean pretest score of 7.40 ($SD = 2.37$) and a mean posttest score of 9.06 ($SD = 2.62$). A paired-samples $t$ test found this increase to be statistically significant with a medium effect size, $t(66) = -5.64, p < .05, d = 0.66$. Responses of high school students resulted in a mean pretest score of 7.44 ($SD = 2.21$) and a mean posttest score of 10.31 ($SD = 2.66$). Analysis via a paired-samples $t$ test determined this increase in score from pretest to posttest to be statistically significant with a low effect size, $t(31) = -5.13, p < .05, d = 0.37$. While no significant difference was found between students’ distal content knowledge before and after the treatment, these findings on proximal content knowledge gains led to the rejection of the null hypothesis of no difference in students’ agriscience content knowledge before and after experiencing SSI-based instruction.

**Null Hypothesis Two**

The second null hypothesis stated that there is no significant difference between the scientific reasoning ability of secondary agriculture students before and after experiencing SSI-based instruction. Differences between students’ scores on the LCTSR were analyzed collectively and separately for middle and high school. Student responses on the pretest yielded a mean pretest score of 7.23 ($SD = 2.80$) and a mean posttest score of 8.77 ($SD = 3.58$). Analysis via a paired-samples $t$ test found this increase to be statistically significant with a low effect size, $t(34) = -3.19, p < .05, d = 0.47$. Middle school students’ responses yielded a mean pretest score of 7.36 ($SD = 2.74$) and a mean posttest score of 8.75 ($SD = 3.19$). This increase in score was determined to be statistically significant with a low effect size through the use of a paired-samples $t$ test, $t(27) = -2.53, p < .05, d = 0.47$. High school students’ responses
led to a mean pretest score of 6.71 ($SD = 3.20$) and a mean posttest score of 8.86 ($SD = 5.18$). A paired-samples $t$ test found this gain to be not significant, $t(6) = -3.03$, $p > .05$. Because scientific reasoning score gains were found to be statistically significant for all students and for middle school students, the null hypothesis of no difference between students’ scientific reasoning ability before and after experiencing SSI-based instruction was rejected.

**Null Hypothesis Three**

The third null hypothesis for this study stated that there is no significant difference between the argumentation skills of secondary agriculture students before and after experiencing SSI-based instruction. Students completed argumentation scenarios before and after the intervention. Both the number of argument justifications and the quality of those justifications was assessed. Analysis of data was conducted for all students and then separately for middle and high school students. Students’ mean number of justifications on the pretest was 2.26 ($SD = 0.95$), while the mean number of justifications on the posttest was 2.21 ($SD = 0.97$). This decrease in number of justifications was not found to be significant, $t(57) = 0.29$, $p > .05$. The mean justification quality score on the pretest was 1.67 ($SD = 0.85$), while the mean score on the posttest increased to 2.40 ($SD = 0.97$). Using a paired-samples $t$ test, this increase in justification quality was found to be significant with a large effect size, $t(57) = -4.13$, $p < .05$, $d = 0.73$.

Middle school students’ responses yielded a mean number of pretest justifications of 2.07 ($SD = 0.81$) and a mean number of posttest justifications of 1.86 ($SD = 0.89$). This decrease in number of justifications between pretest and posttest was found to be not significant, $t(27) = 1.03$, $p > .05$. With regard to argument justification quality, middle
school students had a mean pretest score of 1.79 (SD = 0.79) and a mean posttest score of 1.86 (SD = 0.80). A paired-samples t test found this increase to be not significant, \( t(27) = -0.372, p > .05 \).

High school students had a mean number of pretest justifications of 2.43 (SD = 1.04) and a mean number of posttest justifications of 2.53 (SD = 0.94). A paired-samples t test found no significant difference between high school students' number of justifications before and after the intervention, \( t(29) = -0.36, p > .05 \). High school students' justification quality scores yielded a mean pretest score of 1.57 (SD = 0.90) and a mean posttest score of 2.90 (SD = 0.80). A paired-samples t test found this increase in quality of justification to be statistically significant with a large effect size, \( t(29) = -5.53, p < .05, d = 2.72 \). Based on the statistically significant gain in the argumentation quality of all students and of high school students, the null hypothesis of no difference in argumentation skills due to the intervention was rejected.

**Null Hypothesis Four**

The final null hypothesis stated that there is no significant difference between the views of the NOS of secondary agriculture students before and after experiencing SSI-based instruction. Students' views on six aspects of the NOS were assessed through multiple items, which were administered to the students before and after the intervention. With regard to whether scientists can accept multiple theories simultaneously to explain a phenomenon, the mean difference between pretest and posttest views was 0.86. A paired-samples t test found this difference to be statistically insignificant, \( t(34) = 1.10, p > .05 \). With regard to whether scientific investigations are influenced by socio-cultural values, the mean difference between pretest and posttest views was 0.29. A paired-samples t test found this difference to be statistically
insignificant, \( t(34) = 0.55, p > .05 \). With regard to whether scientists use their imaginations during scientific research, the mean difference between pretest and posttest views was -0.20. A paired-samples \( t \) test found this difference to be statistically insignificant, \( t(34) = -0.27, p > .05 \). With regard to whether scientific theories are tentative, the mean difference between pretest and posttest views was 0.03. A paired-samples \( t \) test found this difference to be statistically insignificant, \( t(34) = 0.08, p > .05 \). With regard to whether scientists’ observations are influenced by personal beliefs, the mean difference between pretest and posttest views was 0.74. A paired-samples \( t \) test found this difference to be statistically insignificant, \( t(33) = 1.07, p > .05 \). With regard to whether scientists follow a universal scientific method, the mean difference between pretest and posttest views was 1.46, which represents over one category shift. A paired-samples \( t \) test found this difference to be statistically insignificant, \( t(34) = 1.65, p > .05 \).

Based on these findings, the null hypothesis of no significant difference in students’ views of the NOS before and after experiencing SSI-based instruction was retained.

**Conclusions of Findings**

Based on the study’s findings and developments, several conclusions can be drawn. First, students experiencing SSI-based instruction displayed an increase in agriscience content knowledge on all proximal assessments. Both middle school and high school students experienced increased content knowledge on the proximal assessments. Next, students experiencing SSI-based instruction did not display an increase in agriscience content knowledge on the distal assessment. Middle school students experiencing SSI-based instruction displayed increased scientific reasoning ability; however, high school students did not display increased scientific reasoning ability. High school students experiencing SSI-based instruction displayed gains in
argumentation quality, while middle school students did not. Students did not display any gains in number of argument justifications. Finally, students experiencing SSI-based instruction did not display any changes in their views of the NOS.

**Implications from Findings**

**Objective One: Determine the Effects of an SSI-based Instructional Model on Middle and High School Agriculture Student Agriscience Content Knowledge**

Conclusion: Students experiencing SSI-based instruction displayed an increase in agriscience content knowledge on all proximal assessments. Both middle school and high school students experienced increased content knowledge on the proximal assessments. The finding that students displayed an increase in proximal agriscience content knowledge is not surprising, as students engaging in any learning experiences with directed content are expected to gain at least some knowledge of that content (Dewey, 1938). This conclusion implies that SSI-based instruction can be utilized to increase students’ agriscience content knowledge.

Conclusion: Students experiencing SSI-based instruction did not display an increase in agriscience content knowledge on the distal assessment. The finding that students did not exhibit an increase in distal content knowledge is disconcerting, as student performance on distal exams, such as standardized achievement tests, are often viewed as a reflection of teacher quality. At face value, this conclusion would imply that students learned nothing that could impact long-term knowledge during the study, although their short-term knowledge was impacted. Klosterman and Sadler (2011) found that students experiencing SSI-based instruction displayed significant gains on distal assessments, which questions the conclusion of the present study. As with the Barab, et al. (2007) study, which posited that a ceiling effect could have caused the lack
of significance found on students’ distal knowledge gains, a closer examination of the circumstances arising during the study may reveal causes of this lack of transferred knowledge from short-term to long-term. The study utilized a convenience sample of teachers rather than the originally intended sample of expert teachers, implying that teachers may not have been well-versed in methods of instruction required by the study, including inquiry-based instruction, questioning methods, and facilitation of discussion. Teachers also employed a maximum of six weeks of instruction during a 14 week timeframe, implying that students were engaged in other activities during approximately eight weeks of the study. While the lessons were organized to be delivered in a manner that could reinforce previous learning, the space between lessons and teachers’ lack of expertise in utilizing the required teaching methods in the lessons could have reduced the amount of knowledge students were able to gain over an extended span of time.

Further, informal conversations with teachers implied that students were fatigued toward the end of the study during completion of assessments. This student fatigue in completing assessments and declining motivation to participate in the study could have impacted students’ desire to put forth effort on posttests. According to Wlodkowski’s motivation theory (1977), grades, novelty, initial interest, and variety each serve to motivate students to perform. Pretests were administered in a situation lending students to high motivation – the study, class, and teacher were each new and different. After 14 weeks, factors could have elicited less motivation from students – the course, teacher, and study were no longer novel, and students’ grades were not impacted by their performance on the assessments. This confounding variable of student motivation, paired with the increased length of the study and great length of time not pertaining to
the study, could have impacted students’ performance on distal assessments, thus causing the lack of a significant finding. This position is further supported by the large standard deviation on students’ posttests. While the standard deviation on the pretest was 3.27, indicating a relatively small degree of variation in students’ scores on the 30-item assessment, the standard deviation on the posttest was 13.93, which indicates that students’ scores were very different from one another. This difference could be explained by students’ varying degrees of motivation to put forth effort on the posttest. Because students’ level of effort may have been a confounding variable leading to the results, the four-point increase in students’ mean distal score is cause to continue investigating the impact of SSI-based instruction on students’ distal agriscience content knowledge.

**Objective Two: Determine the Effects of an SSI-based Instructional Model on Middle and High School Agriculture Student Scientific Reasoning Ability**

Conclusion: Middle school students experiencing SSI-based instruction displayed increased scientific reasoning ability. High school students did not display increased scientific reasoning ability. The impact of SSI-based instruction on scientific reasoning ability has been previously measured by multiple instruments, each with different findings. The results of this study add to the body of knowledge regarding the relationship between SSI-based instruction and scientific reasoning, yet are neither fully supported nor fully unjustified by previous research. The finding that students experiencing SSI-based instruction displayed increased scientific reasoning ability is partially supported by qualitative work by Barab, et al. (2007), who found that students experiencing SSI-based instruction displayed high socioscientific reasoning skills. However, Barab, et al. also found areas of weakness in certain aspects of students’
scientific reasoning; these alternate findings were unearthed by methods of qualitative research, and were not able to be explored in the current quantitative study. The study by Sadler, et al. (2011) found no significant difference in the socioscientific reasoning abilities of high school students before and after engaging in SSI-based instruction, which supports the current study’s finding that high school students did not display increased scientific reasoning ability.

The finding that middle school students displayed a significant increase in scientific reasoning ability while high school students did not is surprising. Typically, one expects students with more education to be more cognitively advanced. However, middle school students in this sample could have been cognitively able to utilize formal operations required by scientific reasoning, while the high school students may not have yet progressed past concrete operational reasoning (Piaget, 1981). While it was expected that individuals in this study would follow the typical cognitive developmental timeline, developing structures required to utilize formal operations around age 11, previous research states that many individuals never develop skills to utilize these structures (Wadsworth, 1986). In this study, high school students may not have developed the skills to conduct scientific reasoning, while middle school students may have been cognitively ready to utilize these skills.

Also providing implications stemming from this finding is the notion of achievement loss. Alspaugh (1987) found that students experience a decline in achievement from middle to high school as a result of alterations in many aspects of the educational environment. Because Agriscience Foundations is a beginning-level course, all but three of the high school students in this study were in ninth grade. This achievement
loss may have contributed to the findings in this study. The increase in high school
students’ scientific reasoning scores, although not statistically significant, implies that
future studies may employ different circumstances that result in significant scientific
reasoning improvement.

Objective Three: Determine the Effects of an SSI-based Instructional Model on
Middle and High School Agriculture Student Argumentation Skills

Conclusion: High school students experiencing SSI-based instruction displayed
gains in argumentation quality, while middle school students did not. Students did not
display any gains in number of argument justifications. The finding that students
experiencing SSI-based instruction displayed gains in argumentation quality is
supported by previous research (Dori, et al., 2003; Tal & Hochberg, 2003; Zohar &
Nemet, 2002). The finding that middle school students did not display statistically
significant gains in argumentation quality is also supported, as research by Osborne, et
al. (2004) found that while eighth-grade students who were exposed to argumentation
content through an SSI context displayed gains in argumentation quality, these gains
were not significant. The finding that students did not display gains in the number of
argument justifications offered is contradicted by Tal and Hochberg’s (2003) study.
However, Tal and Hochberg utilized qualitative means to determine the difference in
argumentation skills before and after SSI-based instruction, and so the increase in
number of justifications found may not have been statistically significant.

These conclusions imply that while SSI-based instruction may be of value in
improving students’ argumentation skills, confounding factors, such as perceived time
permitted, writing skills, and student motivation may have impacted middle school
students’ argumentation quality. While the differing levels of motivation of middle and

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high school students has already been discussed previously, argumentation quality was a product of both depth of argument development and writing ability. Time and space to write were not limited to the students; however, the page on which the scenario was written and teacher behaviors may have implied limits to either time allowed or space to provide an answer. High school students may have had a higher writing ability than middle school students, enabling them to write higher quality arguments more succinctly, while middle school students may have lacked the writing ability to state arguments of quality in the space and time perceived to have been provided. This position is supported by students’ decrease in number of justifications; rather than forgetting about certain argument justifications, students could have chosen to include justifications of greater impact over those of lesser impact, and refrained from including all justifications due to perceived limitations in space and time. These uncontrolled variables imply that while argumentation quality may be positively impacted by SSI-based instruction, the cognitive maturity of middle and high school students, paired with student perceptions of assignment limitations, may impact the quality of students’ arguments.

Objective Four: Determine the Effects of an SSI-based Instructional Model on Middle and High School Agriculture Student Views of the NOS

Conclusion: Students experiencing SSI-based instruction did not display any changes in their views of the NOS. The finding that students experiencing SSI-based instruction did not display any changes in their views of the NOS are challenged by other studies with opposing findings, but supported by findings of studies utilizing the same instrument. Studies using a variety of qualitative and quantitative methods conducted by Zeidler, et al. (2009), and Wong, et al. (2008) found that students
exposed to SSI-based instruction exhibited changes in their views of the NOS. However, Callahan (2009) utilized the VOSE to determine the impact of a semester-long SSI-based curriculum on students’ views of NOS, and found no statistical differences. Callahan cited a lack of differentiation between naïve and more sophisticated views of NOS on the VOSE and respondent fatigue as potential reasons for the lack of a difference, which could be the case with the current study as well. Further, Khishfe and Lederman (2006) found that explicit instruction focusing on NOS was crucial in altering students’ views of the NOS. Because explicit NOS instruction was not a component of this study, Khishfe and Lederman (2006)’s findings would imply that the results of this study would be expected.

**Conclusions of Research Methods**

The convenience sample utilized in this study and the high attrition rate experienced limit the generalizability of the findings’ conclusions. However, differences in the study’s designed and realized research methods lead to conclusions that can be useful in guiding the development of procedures in future studies of a similar nature. First, teachers displayed high attrition. Seven of the eleven teachers originally enrolled in the study dropped out before the study’s completion. Those completing the study did not display common characteristics different from those that dropped out. Next, teachers could not complete the lesson plans that acted as the study’s treatment. Many teachers dropped out of the study due to their inability to complete lesson plans. However, even those that enrolled in the study were unable to complete the entire 45 lessons during the study’s 14-week duration. Teachers completed between 34 and 37 lessons. Finally, students displayed fatigue toward the final weeks of the study. Their posttest scores on the distal agriscience content knowledge assessment displayed
great variance which was not present on the pretest. This variance is presumed by the researcher to be the result of varying levels of effort put forth by the students, as many of the posttest scores were drastically lower than the pretest scores.

**Implications from Conclusions of Research Methods**

Conclusion: Teachers displayed high attrition. The high percentage of teachers that opted to drop out of the study speaks volumes about the challenges of utilizing a convenience sample of teachers in a study so dependent on teacher performance and effort. The study moved from a purposive sample of expert teachers to a convenience sample of all teachers after numerous teachers contacted the researcher displaying interest in the study’s treatment and requesting to attend the training. Previous research has identified accessibility to resources as a barrier to integrating science in secondary agricultural education (Myers, Thoron, & Thompson, 2009). Before requesting to participate in the study, teachers became aware of participant’s access to nine full weeks of daily lesson plans and materials designed to integrate science concepts into the context of agricultural education. Only by consenting to participate did teachers get access to the lesson plans. Conversations with teachers during the training session uncovered some of the teachers’ motivators for attending, primarily being a desire to obtain pre-made, thorough lesson plans that aligned with standards and would be impressive to administrators. Many of these teachers later dropped out of the study, implying that teachers enroll in studies for different reasons, and some of those reasons may not be conducive to the study’s success.

Conclusion: Teachers could not complete the lesson plans that acted as the study’s treatment. Informal conversations with teachers indicated that they were delivering lesson plan activities as designed. However, the entire treatment was not
able to be delivered in any case. Teachers’ inability to complete the lesson plans implies that, to some degree, teachers do not teach according to written lesson plans. Each lesson plan activity was written in detail and included guiding questions to aid in aligning discussion with lesson objectives. Teachers unaccustomed to utilizing such prescribed plans may have difficulty adhering to those written by someone else. Further, each lesson activity was accompanied by a recommended time requirement to ensure that each lesson plan would be approximately 45 minutes in duration. Informal conversations with teachers revealed that many of the activities were extended in length, and so lesson plans often took two days to complete instead of one. The increased length of time required to complete lesson activities speaks to the teachers’ ability to carry out activities using methods with which they may be unfamiliar. Each of the teachers reported being at least somewhat familiar with teaching methods considered to be complementary to SSI-based instruction, including problem solving, inquiry-based instruction, and experiential learning. However, teachers’ inability to conduct lesson activities in a timely fashion suggests that these teaching methods may not be utilized on a regular basis in their classrooms. These results imply that requiring students to practice classroom behaviors different from those to which they are accustomed increases the length of time required by teachers and students to carry out the activities.

Increased time for lesson activities accounted for a portion of the increased study duration. Another factor leading to teachers’ inability to complete the lesson plans was the amount of time teachers devoted to responsibilities other than teaching in the classroom. Management of agricultural facilities, preparing and accompanying students
to county fairs and National FFA Convention, attending livestock shows, participating in school-based professional development, and assisting with standardized test preparation were only a fraction of the reasons teachers gave for falling behind in delivering lessons, implying that secondary agriculture teachers have many responsibilities that keep them from teaching. A recent study by Torres, Ulmer, and Aschenbrener (2008) found that approximately half of the responsibilities of an agriculture teacher were those not related to teaching in the classroom. These results, paired with those from the current study, indicate that the large amount of time spent outside of the classroom present a challenge for researchers examining teaching methods in agricultural education.

Conclusion: Teachers indicated that students displayed fatigue toward the final weeks of the study. This displayed decrease in motivation and interest on the part of the students as shown on posttests implies that factors such as instrumentation, teachers’ behavior, and the length of the study can negatively impact students’ willingness to put forth effort on a study’s posttests. Each of the instruments utilized in this study was lengthy, required considerable effort, and was designed and/or validated by individuals outside of the study’s population. The distal content knowledge assessment was validated by a group of college juniors. The LCTSR and VOSE were developed to be utilized by college students. The argumentation rubric has been utilized previously in oral assessments rather than written assessment, as was conducted in this study. The instruments were originally selected for use in this study because of the cited appropriateness for these instruments for use with high school students. However, the instruments were never validated for use with middle school students. Because the vast
majority of the study’s sample were middle school students or high school students recently transferring from middle school, the terminology used and level of comprehension required by these instruments may have contributed to students’ growing fatigue.

Because teachers did not audio record their lessons, teacher mood and behavior could only be assumed to have no impact on the students’ level of motivation. However, the teachers’ increasing levels of guilt, frustration, or anxiety over falling behind on the delivery of lessons could have negatively impacted students’ motivation. Because the teachers did not experience success in completing the study or staying on the targeted course throughout the study, their behavior could have displayed to students their own possible fatigue.

Paired with teachers’ fatigue is the increased duration of the study, which could have negatively impacted students’ motivation on posttests. During a routine conversation, one teacher mentioned that her students were tired of hearing about cultured meat after the winter break. The students were originally told that the unit would last until the end of November; this increase in duration could have caused increased student fatigue. The likely reasons for student fatigue listed here, including inappropriate instrumentation, negative teacher behavior, and the unexpected increase in study duration all provide researchers with guidelines for reducing the potential for student fatigue in future studies.

Discussion

This study offers findings which indicate that an SSI-based instructional model can be effective in improving secondary agriculture students’ agriscience content knowledge, scientific reasoning ability, and argumentation skills. However, the
outcomes of SSI-based instruction are influenced by numerous factors. Many factors, such as teacher selection, duration, treatment fidelity, and instrumentation altered the results of this study, limiting the practical application of the findings and implications. A discussion of how research in agricultural education can overcome the challenges found in this study is warranted in order for the theory of SSI-based instruction to be established as a practical, impactful teaching method.

Differences between Science Education and Agricultural Education

Although widely studied in science education, this study represents the first to examine SSI-based instruction in agricultural education. The differences between science and agricultural education merit discussion of how SSI-based instruction and related research might be realized differently in the two settings. The teachers in the two disciplines are quite different, and studies utilizing teachers can be impacted due to these differences.

How agriculture teachers identify themselves professionally is often different to the professional identity of other teachers, including science teachers (Shoulders & Myers, 2012). While science teachers often enter the profession for reasons related to helping children learn, many agriculture teachers enter the profession because of their love of agriculture rather than for a love of children. The responsibilities of the two teachers contrast as well; science teachers spend most of their salaried time either planning for lessons or delivering lessons, most often in a classroom. Their standards and curriculum by which they teach are set for them, and so they have little work in the way of curriculum design. The science teacher must display quality teaching to impact student learning, and is held accountable by a standardized test measuring students’
science content knowledge. Finally, the science teacher is a crucial part of all schools, as science classes are part of the core academics required for secondary students.

Agriculture teachers design their own curriculum based on standards set by the state, and are not held accountable for their teaching quality by a directly-related standardized test. These teachers also spend approximately half their salaried time fulfilling responsibilities unrelated to instruction. When focusing on instruction, agriculture teachers are expected to utilize both formal classrooms and agricultural laboratories, although the type of laboratories available to each teacher varies by school. Often, these agricultural laboratories require maintenance and are expected to provide products that turn a profit to sustain at least a portion of the agricultural education program. Further, administrators often expect agriculture teachers to fill additional roles as needed; frequently, agriculture teachers grow ferns for proms, maintain the school’s landscaping, perform maintenance as needed with tools in the welding/mechanics/carpentry laboratory, and cook for school events. Finally, agriculture teachers must recruit students and maintain high enrollment in order to keep their jobs, as agricultural education is not required in school and students must elect to enroll in the program.

These differences between science and agriculture teachers and their teaching situations point to some differences in how researchers can best work with teachers in order to realize the benefits of SSI-based instruction. Researchers must approach the two types of teachers differently, as their reasons for participating in studies, and subsequently their ability to adhere to study requirements, may vary. In this study, many of the teachers that enrolled did so in an effort to reduce the amount of time they had to
devote to planning for classroom instruction. However, studies that examine the effects of new teaching methods require that those methods be carried out in a quality fashion; delivering instruction in this format requires active, organized teaching methods. The teachers motivated to participate by the promise of pre-made lesson plans may not have shared the same dedication to active, quality, and organized teaching that was required by the lesson plans. This difference in researcher expectations (realized through lesson plan requirements) and teacher behaviors was fueled by the researcher’s inaccurate assumption that the agriculture teachers shared the professional identity of other teachers, and could have been avoided if the study had been designed to accommodate the realities of agriculture teachers’ motivators and behaviors.

**Designing Teacher-friendly Studies**

Essentially, the procedures of this study were unable to be carried out as designed because of the great differences between the researcher’s expectations for teachers and actual teacher behaviors. The researcher expected teachers to be able to deliver lesson plans as designed, record each lesson and upload audio recordings onto a file shared with the researcher, record and send attendance each day, and administer all pretests and posttests at the appropriate times during the study. Teachers were made aware of these expectations and fully accepted these terms when agreeing to participate in the study. Many teachers asked to be removed from the study when they realized they were unable to meet these expectations. Those that remained in the study were unable to meet these expectations as well, and submitted what they were able to, which led to incomplete data for use in the study.
A particularly impactful factor in teachers’ level of success regarding delivery of lesson activities is teacher training. Efforts were made to train teachers in a uniform fashion, whether in person or online, teachers engaged in a one-hour training which focused on the tenets of SSI-based instruction, discussed differences between the teaching style of subject-based instruction and SSI-based instruction, and detailed the specific requirements of the study. The training session also enabled teachers to explore one week of lessons and ask related questions. While this training session did not focus on problem-based learning, inquiry-based instruction, or experiential learning, the tenets of these theories were present in the lessons. Previous literature indicated that even agriculture teachers who have extensive training in inquiry-based instruction report utilizing inquiry-based teaching strategies approximately two times per week and only report utilizing student-based inquiry activities once per month (Myers, Thoron, & Thompson, 2009). The study’s lesson plans intended teachers to utilize these methods with every lesson. Designing training that has the content and duration needed to impact teachers’ ability to deliver lessons is crucial to helping teachers successfully complete study requirements.

While study methods aligning with research ideals make for solid studies, those studies are only useful if they are able to be carried out. Research in social science requires a balance between rigorous research methods and those that are practical in given situations. In this study, many of the study’s designed methods were intended to make a more rigorous study; however, these increased responsibilities on teachers made the attrition rate much higher than what is typically seen in these types of studies. Understanding teachers’ behaviors can help researchers design studies that align with
teachers’ abilities and the realities of what is able to be done in an agricultural education program. By working more closely during the design phase of the study, aspects requiring teacher effort, such as lesson plan delivery, methods to ensure treatment fidelity, and test administration can be developed in a way that better aligns with teachers’ abilities.

Teaching has been reported to be an increasingly difficult occupation as increased accountability is partnered with more “diverse and needy student populations” (Smylie, 1No9, p. 59). While a purposive sample of accurately identified expert teachers may have led to a decrease in the attrition rate of this study, students are taught every year by teachers who are not experts and suffer a decrease in teaching quality due to external pressures. SSI-based instruction can provide agriculture teachers with a tool helpful in maintaining quality instruction, as it has been shown to improve students’ content knowledge in agriscience. SSI-based instruction should be designed in a way that can help teachers maintain or improve teaching quality while meeting the demands of today’s teaching environments.

**Recommendations for Future Research**

Numerous follow-up studies could help the profession gain a more thorough understanding of how SSI-based instruction can impact secondary agriculture students. However, the above discussion warrants several recommendations to guide researchers when developing studies. First, studies depending on teachers can only be carried out successfully when the methods are designed in a way that encourages teacher cooperation and success. Therefore, teachers should be included in as much of the design process as their schedules will allow. Partnerships between researchers and teachers during the development process can aid in developing and field testing lesson
plans, determining the activities and SSI(s) appropriate for student groups, and designing methods that will be plausible in agricultural education programs. Teachers are responsible for designing their own lesson plans, and therefore may feel more comfortable teaching from treatment lesson plans they have helped develop. This design process can increase the level of understanding and practice teachers have with pertinent teaching methods, increasing the duration and meaning of training they have received. Further, research methods guided by both teachers and researchers can ensure a realistic balance between rigorous and plausible procedures. At the very least, teachers will gain a sense of the importance of carrying out methods designed to increase the validity of the study.

**Opportunities for Future Research**

This study served as the first investigating SSI-based instruction in secondary agricultural education. Therefore, recommendations impacting future research can be made in an effort to further understand how SSI-based instruction can benefit agriculture students. Recommendations highlight the need for future research in the areas of research methods, populations and samples, intervention, and instrumentation.

This study explored the effects of SSI-based instruction in a pre-experimental fashion. Future studies are needed to explore the impacts of SSI-based instruction compared to other methods of instruction. Additionally, longitudinal studies could help determine the impact achievement loss between middle school and high school has on students’ learning through SSI-based instruction. Because research in the social sciences cannot be understood holistically through quantitative methods, qualitative research should be conducted in order to better understand how aspects of SSI-based instruction are utilized and impact students.
The different populations and samples of teachers and students in agricultural education provide several areas for future inquiry. Studies utilizing SSI-based instruction should utilize a variety of teachers and samples, including expert teachers, national samples, and teachers involved in specific training endeavors to better understand how teacher variables impact the use of SSI-based instruction. Studies utilizing SSI-based instruction should also utilize a variety of student samples, including specific grade levels, states, national samples, school achievement levels, socio-economic status levels, groups of varying ethnicity, and FFA involvement to gain a better understanding of how SSI-based instruction is impacted by student variables. Finally, this study represented the first investigating SSI-based instruction in agricultural education. A follow-up study involving interviews of the teachers enrolled in this study should be conducted in order to better understand the qualities of the instruction that enhanced or deterred learning.

The intervention utilized in this study focused on one SSI and employed specific activities in each of the lessons. The wide array of SSIs requires that studies investigating the impact of different SSI topics be conducted to determine whether certain SSIs are more impactful than others. Additionally, the experiential tenets of agricultural education merit exploration into the impact various activities have on student learning in SSI-based instruction. The complications agriculture teachers have completing lessons in the classroom appears to be unique to this type of teacher, as science teachers typically utilize only classroom-based learning settings. Further research incorporating various agricultural laboratories into SSI-based instruction can improve agriculture teachers’ abilities to consistently teach SSI-based lessons while
maintaining their responsibilities in laboratories. Additionally, SSI-based instruction may impact students differently in these agricultural laboratories, and investigation of these laboratories is recommended. The duration of studies investigating SSI-based instruction varies greatly. Further research on the optimal duration of an SSI-based instructional unit is warranted.

The instruments employed in this study were determined to accurately and completely measure the constructs to which they were aligned by validity and reliability measures. However, the nature of social science research implies that many constructs can be accurately measured in a holistic fashion through multiple instruments. This study utilized specific instruments to test SSI-based instruction’s impact on students’ agriscience content knowledge, scientific reasoning ability, argumentation, and views of the NOS. Because these assessments represent the constructs under study, further investigations should utilize these and other instruments to gain a more holistic understanding for how SSI-based instruction impacts these learning outcomes. The impact of SSI-based instruction on students’ argumentation skills should be measured through oral assessment in order to eliminate writing ability as a confounding variable.

This study examined a limited number of aspects of scientific literacy. Because learning outcomes related to scientific literacy incorporate additional facets, further study should be conducted to investigate how SSI-based instruction impacts other aspects of students’ scientific literacy. The role of SSI-based instruction in society warrants further study on the impact of societal influence, including media, family discourse, and individual and family values on decisions made related to SSIs. Previous research stated that SSI-based instruction had positive impacts on student interest. Further
research should be conducted to determine how SSI-based instruction impacts students’ attitudes toward the subject and toward the class. Finally, among the goals of SSI-based instruction is educated decision-making. Future studies can be conducted to determine the impact SSI-based instruction has on students’ choices regarding the SSI.

**Recommendations for Curriculum Development**

This study found that SSI-based instruction can assist students in increasing agriscience content knowledge, scientific reasoning ability, and argumentation skills. These results yield several recommendations for individuals responsible for curriculum development in secondary agricultural education. First, based on previous research in SSI-based instruction, SSI selection should be the product of student interest. Further, development of an SSI-based instructional unit for use in this study indicated that the SSI should align with course standards that address multiple aspects of the issue. Based on the development of the SSI-based instructional lessons, teaching activities should align with tenets of experiential learning, inquiry-based instruction, and SSI-based instruction. Findings of this study indicate that the use of guiding questions throughout lessons can aid students in developing argumentation and scientific reasoning skills. Based on the findings of this study, more curriculum materials should be developed to assist teachers in incorporating SSI-based instruction into specific courses. Based on the teacher mortality rate of this study and the recommendations of previous studies, teachers should be involved in the curriculum development process. Finally, when planning course curriculum, consideration of areas appropriate for SSI-based instruction should be identified, as this method of instruction is more appropriate for certain content areas than others.
Recommendations for Preservice and Inservice Teacher Education

This study found that student achievement in agriscience content knowledge, scientific reasoning ability, and argumentation quality can be raised through the use of SSI-based instruction. Teachers utilizing SSI-based instruction can be assisted through recommendations for preservice and inservice teacher education. First, based on the findings of this study, teachers should be encouraged to utilize SSI-based instruction in secondary agricultural education. The agricultural context of many SSIs can offer teachers a means for highlighting the scientific content in agriculture. Teachers engaging in SSI-based instruction should focus on a variety of learning outcomes related to scientific literacy. This study shows that student learning can be enhanced in a variety of areas outside of content knowledge. The skills regarding decision making and reasoning should also be outcomes of SSI-based instruction. Teachers should be educated in methods of holistic curriculum development, as SSI-based instruction requires considerable reorganization of course standards, units, and lessons. Based on the tenets of SSI selection, teachers should be guided in the identification of SSIs appropriate for the context of agriculture. Teachers should be trained in SSI-based instruction through methods providing for increased duration beyond one training session. Teacher educators should educate preservice and inservice teachers in complementary teaching methods, such as experiential learning, inquiry-based instruction, and the use of media to aid teachers in appropriately incorporating activities into SSI-based lessons. Extensive training in these methods should accompany any development related to SSI-based instruction. Partnerships should be made between preservice teachers, inservice teachers, and teacher educators when developing instructional materials to increase teachers’ level of ownership and knowledge of SSI-
based instruction. Finally, teacher educators should observe SSI-based instruction in practice and provide reflections to teachers in order to develop an informal list of best practices for SSI-based instruction in agricultural education.

**Summary**

Chapter 5 offered a summary of the study’s objectives and hypotheses, as well as presented conclusions stemming from the findings. Chapter 5 also provided recommendations for teacher educators and curriculum developers seeking to utilize SSI-based instruction in agricultural education. Finally, the chapter offered recommendations for future research to enhance the body of knowledge regarding SSI-based instruction in agricultural education. The objectives of the study were: (a) to determine the effects of an SSI-based instructional model on secondary agriculture student agriscience content knowledge, (b) to determine the effects of an SSI-based instructional model on secondary agriculture student scientific reasoning ability, (c) to determine the effects of an SSI-based instructional model on secondary agriculture student argumentation skills, and (d) to determine the effects of an SSI-based instructional model on secondary agriculture student views of the NOS. Null hypotheses for the study included: (a) there is no significant difference between the agriscience content knowledge of secondary agriculture students before and after experiencing SSI-based instruction, (b) there is no significant difference between the scientific reasoning ability of secondary agriculture students before and after experiencing SSI-based instruction, (c) there is no significant difference between the argumentation skills of secondary agriculture students before and after experiencing SSI-based instruction, and (d) there is no significant difference between the views of the NOS of secondary agriculture students before and after experiencing SSI-based instruction.
The study’s findings indicated that SSI-based instruction is effective in increasing secondary agriculture students’ agriscience content knowledge, scientific reasoning ability, and argumentation skills. These findings, combined with previous research, provided recommendations for preservice and inservice teachers, curriculum developers, and researchers seeking to further expand upon the available knowledge related to how SSI-based instruction can impact student learning in agricultural education.
## APPENDIX A
### INSTRUCTIONAL PLANS

<table>
<thead>
<tr>
<th>Daily Plan</th>
<th>Socio-Scientific Issues Instruction – Day 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lesson Title:</strong></td>
<td>Cultured Meat – An Introduction</td>
</tr>
<tr>
<td><strong>Unit Title:</strong></td>
<td>The Introduction of Cultured Meat</td>
</tr>
<tr>
<td><strong>Course:</strong></td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>45 minutes</td>
</tr>
</tbody>
</table>

### Materials, Supplies, Equipment, References, and Other Resources:
- “What’s a Burger Without a Cow?” article (classroom set)
- Argumentation Pretest (classroom set)
- 3 highlighters per student (optional – can be replaced with one writing instrument)
- 3 index cards per student
- Question Wall Headings (one set), posted on classroom wall in a “web” layout

### Agriscience Foundations Standards:
- 3.08 – Evaluate advances in biotechnology that impact agriculture (e.g. transgenic crops, biological controls, etc.)
- 3.06 – Interpret, analyze, and report data

### Essential Question:
Why do certain organizations want to introduce cultured meat into the nation’s food supply?

### Daily Objectives:
1. Define cultured meat.
2. Explain the reasons individuals want to introduce cultured meat into the nation’s food supply.
3. Develop an initial position regarding the development of cultured meat.
### Introduction (Interest Approach)

**Estimated Time: 10 minutes**

Students will read the “What’s a Burger Without a Cow?” article individually, using three highlighters or marks (underline, circle, “star”) – one color or mark will represent items they believe to be true, another will represent items they believe to be false, and the third will be used to mark items they have questions about or are unsure of.

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### Learning Activity 1

**Estimated Time: 15 minutes**

**Instructor Directions / Materials**

Before any discussion, students will complete the Argumentation Pretest. This should be turned in.

**Brief Content Outline**

For the pretest, students will not be given any guidance in developing their arguments.

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### Learning Activity 2

**Estimated Time: 10 minutes**

**Instructor Directions / Materials**

After all pretests are turned in, the teacher will ask students to share items they think are true or false, or have questions about, and ask them why they feel this way. Students should be encouraged to respond to one another's ideas and questions.

*Guiding questions – Why do you think that is true/false? How might we find the answer to that question?*

**Brief Content Outline**

Cultured meat – meat products from animals’ cells that are grown in a laboratory environment. Cultured meat does not require the killing of the animal.

Synonyms – artificial meats, in-vitro meats, lab-grown meat
Summary (Review) | Estimated Time: 10 minutes
---|---
Each student should receive 3 index cards. Using the article from the interest approach as a guide, have students identify questions they have regarding the introduction of cultured meat into the nation’s food supply related to the following five categories:
- Food safety/human health
- Environmental impacts
- Economic impacts
- Animal industry/animal welfare
- Other

Students will write questions on index cards and post on a wall in the classroom under the appropriate heading (these should already be posted on the wall in the room in a “web” layout so students can post their questions around the appropriate heading). They can write questions in any of the categories, and can write more than one question in a category, but they must use each of their three index cards.

The teacher should inform students that the class will work to answer some of these questions through the upcoming nine weeks.

Evaluation
Students will turn in their argumentation pretests to the teacher.

Items Students Turn In
Argumentation Pretest
Defending Food Safety

Posted at 12:30 AM on December 7, 2009 by Shawn Stevens

What's A Burger Without A Cow?
The burger of the future may soon be here.

And, what's the burger of the future? Well, it's a beef patty, actually. It will look, smell and taste the same as a burger does today. The only difference is that there may no longer be a need for the cow.

Technological advancements across the food industry, along with those in the bio-sector, have resulted in recent breakthroughs which could make artificial (or, in-vitro) meats available in grocery stores as early as 2012. Using embryonic cells to grow muscle tissue in a steel tank (imagine growing meat in a test tube), the process will likely be similar in many ways to yogurt production.

While the idea of eating artificially grown meat might seem somewhat "distasteful," the breadth of new incentives may eventually outweigh any potential consumer hesitance.

For starters, the meat of the future will be made to taste as good or, perhaps, even better than its naturally grown counterparts. In addition to tasting great, it will also likely be healthier because scientists will be able to manipulate the nutritional content to optimal levels. Imagine a burger, for instance, that helps to prevent, rather than promote, heart attacks.

And, while promoting long term health benefits, lab grown meat, whether chicken, beef, pork or lamb, will be inherently safe.

According to Jason Matheny of the research group New Harvest, the possibility of pathogenic contamination should become almost nonexistent. If we could produce meat in sterile conditions that are impossible in conventional animal farms and slaughterhouses, added Matheny, we could substantially reduce the number of food-borne illnesses and ancillary costs associated with outbreaks.

In a recent interview with CNN, Matheny also stated that Bio-meat could substantially reduce other human illnesses as well. These would include ailments "like swine flu, avian flu, and mad cow disease."

Beyond food safety, the financial benefits for companies producing meat without the expense of raising it are tremendous. It takes 700 calories of feed to produce a 100 calorie piece of beef. And, this does not take into account the other logistical problems of using meat off the hoof. "When we grow only the meat we can eat, it's more efficient," said Matheny. "There's no need to grow the whole animal and lose 75 to 95 percent of what we feed it."

Ultimately, with lab engineered meat, food companies would no longer have to pay for raising, feeding, housing and providing veterinary treatment to live animals.

So, what’s a burger without the cow? Perhaps a very "good" idea.
The Production of Cultured Meat and
It’s Introduction into the Nation’s Food
Supply

Environmental Impacts
Animal Industry/Animal Welfare

Food Safety/Human Health
<table>
<thead>
<tr>
<th>Economic Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other</td>
</tr>
</tbody>
</table>
### Daily Plan

<table>
<thead>
<tr>
<th>Lesson Title:</th>
<th>Food Safety Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Title:</td>
<td>Food Safety</td>
</tr>
<tr>
<td>Course:</td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>45 minutes</td>
</tr>
</tbody>
</table>

### Materials, Supplies, Equipment, References, and Other Resources:
- Classroom computer hooked to a projector
- Food Safety Pretest
- Food Safety Concerns powerpoint *Note – please check that all hyperlinks work before class*
- Justification Evaluation Sheets (classroom set)
- GMO Products Packets (one per group of 3 students)
- GMO Benefits and Drawbacks Sheets (classroom set)
- Index cards (classroom set)

### Agriscience Foundations Standards:
- 3.08 – Evaluate advances in biotechnology that impact agriculture (e.g. transgenic crops, biological controls, etc.).
- 1.04 – Examine the role of the agricultural industry in the interaction of population, food, energy, and the environment.
- 3.06 – Interpret, analyze, and report data.

### Essential Question:
Why are consumers concerned with food safety?

### Daily Objectives
1. Identify historical events that have led consumers to elicit concern regarding food safety.
2. Identify biological innovations that have impacted the food supply.
3. Evaluate the potential benefits and drawbacks of advancements in biotechnology.
<table>
<thead>
<tr>
<th>Introduction (Interest Approach)</th>
<th>Estimated Time: 5 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>On a projector linked to a computer, show students the FDA’s “Current Meat and Poultry Recalls” webpage (<a href="http://www.fsis.usda.gov/fsis_recalls/Open_Federal_Cases/index.asp?src_location=Content&amp;src_page=FSISRecalls">http://www.fsis.usda.gov/fsis_recalls/Open_Federal_Cases/index.asp?src_location=Content&amp;src_page=FSISRecalls</a>)</td>
<td></td>
</tr>
</tbody>
</table>
| Explain to students that the webpage is a list of all current recalled meat and poultry products in the US – the recalls can be limited to a certain region or nation-wide.  

Guiding questions – How many recalls were there since the beginning of the school year? What about since the beginning of the summer? What are some common reasons listed for the foods being recalled? Do you think you may have eaten any of these products? | |

<table>
<thead>
<tr>
<th>Learning Activity 1</th>
<th>Estimated Time: 10 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructor Directions / Materials</td>
<td>Brief Content Outline</td>
</tr>
<tr>
<td>Have students take the Food Safety Pretest. Appropriate testing conditions should be enforced. These should be turned in upon completion.</td>
<td></td>
</tr>
</tbody>
</table>
Learning Activity 2

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
</tr>
</thead>
</table>
| Give each student an index card and instruct them to draw a checkmark on one side of the card and an X on the other side. Explain to the students that the class will be evaluating some recent major food safety concerns people have had that have impacted the food production industry. Students will take notes on the food safety issue using the attached Justification Evaluation Sheet while the teacher introduces the content through the Food Safety Concerns powerpoint. After each issue is introduced, students will evaluate their notes and hold up their index cards, showing the checkmark side if they feel the concern was legitimate and justified and the X side if they feel the concern was unfounded and unjustified. After students hold up their cards, briefly ask students to explain why they feel the concern was justified or unfounded. *Guiding questions – Why do you feel that concern is justified/unjustified? Why do you think people are concerned if the concern is unjustified?*

<table>
<thead>
<tr>
<th>Estimated Time: 10 minutes</th>
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</thead>
<tbody>
<tr>
<td>Brief Content Outline</td>
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</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Beef</td>
<td></td>
</tr>
<tr>
<td>a. E. coli</td>
<td></td>
</tr>
<tr>
<td>b. Mad Cow Disease (Bovine Spongiform Encephalopathy)</td>
<td></td>
</tr>
<tr>
<td>c. Foot and Mouth Disease</td>
<td></td>
</tr>
<tr>
<td>d. Hormone additive controversy</td>
<td></td>
</tr>
<tr>
<td>2. Swine</td>
<td></td>
</tr>
<tr>
<td>a. H1N1</td>
<td></td>
</tr>
<tr>
<td>3. Poultry</td>
<td></td>
</tr>
<tr>
<td>a. Avian Influenza</td>
<td></td>
</tr>
<tr>
<td>4. Lettuce</td>
<td></td>
</tr>
<tr>
<td>a. E. coli</td>
<td></td>
</tr>
<tr>
<td>5. Peanut Butter</td>
<td></td>
</tr>
<tr>
<td>a. Salmonella</td>
<td></td>
</tr>
<tr>
<td>6. Sprouts</td>
<td></td>
</tr>
<tr>
<td>a. E. coli</td>
<td></td>
</tr>
</tbody>
</table>
Learning Activity 2

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Estimated Time: 10 minutes</th>
<th>Brief Content Outline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Put students into groups of 3.</td>
<td></td>
<td>1. Terminology</td>
</tr>
<tr>
<td>Explain the definitions of “biotechnology” and “GMOs” to students, and tell the students that they will be examining how different GMOs and their purposes have impacted food safety concerns.</td>
<td></td>
<td>a. Biotechnology – using organisms and their components to make products (includes GMOs)</td>
</tr>
<tr>
<td>Give each student group a packet of “GMO Products” slips. Tell the students that the GMO products listed are currently in various stages of development – not all are commercially available now. Tell the students to arrange the slips of paper into the following categories of goals for food biotechnology: - Overcome agricultural limitations - Increase food quality - Improve human health - Minimize environmental impact</td>
<td></td>
<td>b. Genetically modified foods – alters the genetic makeup of organisms (plants, animals, bacteria). AKA genetically engineered, transgenic</td>
</tr>
<tr>
<td>After student groups have their slips arranged under each of the categories, have a class discussion about why they put certain items in certain categories.</td>
<td></td>
<td>2. Goals of food biotechnology’s innovations:</td>
</tr>
<tr>
<td>Guiding questions – What items did you put under this category? Where did you place this GMO? Why do you think that GMO addresses this concern?</td>
<td></td>
<td>a. Overcome agricultural limitations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i. Salt tolerant plants</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii. Increase in milk production in dairy cows</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iii. Increase growth rates with hormones</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iv. Fruit and nut trees that yield years earlier</td>
</tr>
<tr>
<td></td>
<td></td>
<td>v. Drought or flood resistant crops</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. Increase food quality</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i. Shelf life – Flavr Savr tomatoes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii. Pest resistance – Bt corn</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iii. Disease resistance – cattle resistant to BSE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iv. Taste – increase meat tenderness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. Improve human health</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i. Lactose fortified milk</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii. Reduce “bad” fats, increase good fats</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iii. Rice with increased iron and vitamins</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iv. Bananas that produce human vaccines</td>
</tr>
<tr>
<td></td>
<td></td>
<td>d. Minimize environmental impact</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i. Detect pollutants easily with use of GloFish</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ii. Increase nitrogen efficiency, less fertilizer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iii. Enviropig</td>
</tr>
<tr>
<td></td>
<td></td>
<td>iv. Goat with spider silk</td>
</tr>
</tbody>
</table>
### Summary (Review)

<table>
<thead>
<tr>
<th>Estimated Time: 10 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have students individually evaluate the Benefits and Drawbacks of GMOs sheet. Next to each group of benefits and drawbacks offered on the sheet, have the student circle the checkmark or X indicating whether think that GMOs overall add benefits to that aspect or are overall more detrimental to that aspect. Students will then defend their selections in the “Comments” sections. This should be turned in as students leave.</td>
</tr>
</tbody>
</table>

### Evaluation

Students will turn in their Benefits and Drawbacks justifications and will be assessed formatively by the teacher throughout the lesson.

### Items Students Turn In

**Food Safety Pretest**  
GMO Benefits and Drawbacks Sheet (for classroom use)
## Justifications Evaluation Sheet

**Instructions:** Each of the concerns below has impacted the nation’s perspectives of food safety. Following the information provided by your teacher and powerpoint, use the space below to take notes on the aspects of the concern that you feel are justified (people had reason to be concerned about their food’s safety) or unfounded (people were unnecessarily concerned and their food safety was not really in danger).

Concerns with Beef:

<table>
<thead>
<tr>
<th>The Concern</th>
<th>Justified aspects of the concern</th>
<th>Unfounded aspects of the concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. coli</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mad Cow Disease (BSE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foot and Mouth Disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controversy over Hormone Additives</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Concerns with Swine:

<table>
<thead>
<tr>
<th>The Concern</th>
<th>Justified aspects of the concern</th>
<th>Unfounded aspects of the concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1N1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Concerns with Poultry:

<table>
<thead>
<tr>
<th>The Concern</th>
<th>Justified aspects of the concern</th>
<th>Unfounded aspects of the concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avian Influenza</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Concerns with Crop Products:

<table>
<thead>
<tr>
<th>The Concern</th>
<th>Justified aspects of the concern</th>
<th>Unfounded aspects of the concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. coli in lettuce</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salmonella in peanut butter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. coli in sprouts</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
GMO Products Packet
Cut these into slips of paper to create a separate packet for each student group.

Salt tolerant plants

Increase milk production in dairy cows

Increase growth rate using hormones in livestock

Fruit and nut trees that yield years earlier

Drought and flood resistant crops

Tomatoes with longer shelf life

Plants resistant to certain pests

Cattle that are resistant to mad cow disease

Increase meat tenderness with gene manipulation

Reduce bad fats and cholesterol in meats

Increase good fatty acids in plant oils

Rice with increased vitamins and irons

Bananas that produce human vaccines

Reduce waste excreted by enhancing

Detect pollutants in water with Glofish

Increase nitrogen efficiency in plants for less nitrogen fertilizer

Enviropig digests phosphorus to produce less phosphorus

Goats that produce spider silk to require less building materials
Comments:

Environmental Impacts
• Benefit - reduce fertilizer and pesticide usage, reduce animal wastes
• Benefit - higher animals and plants will reduce burden on limited land and water resources
• Drawback - unknown effects on other organisms

Human Health
• Benefit - could greatly reduce diseases from poor diets of high fat and low quality protein
• Drawback - potential unknown effects of GMVs on human health

Food Quality
• Benefit - enhanced taste and quality

Food Safety
• Benefit - foodborne diseases, a major contributor to illness and death, could be reduced through resistant foods and animals
• Drawback - new regulations protecting food safety don’t have an established successful history
• Drawback - the current threats regarding bioterrorism

Animal Industry and Animal Welfare
• Benefit - fewer resources needed to raise animals
• Benefit - can reduce animals’ need for veterinary care and medicine through more disease-resistant animals
• Drawback - unknown long term effects on species’ and breed’s genetic pools
• Drawback - could cause unknown stresses for animals

Economic Impacts
• Benefit - cheaper, more available foods due to fewer costs when producing foods and more food available
• Drawback - world food production is dominated by a few large companies and the smaller farmer can’t afford to produce foods cheaply

Comments:
Slide 1

Food Safety
Recent Concerns

Slide 2

Concerns in the Beef Industry

- E. coli
  - 2005—5 beef recalls related to E. coli
  - 2006—8 recalls
  - 2007—21 recalls
  - 2009 Recall

Slide 3

Concerns in the Beef Industry

- Mad Cow Disease (Bovine Spongiform Encephalopathy)
  - Is a zoonosis (transferred from animals to humans)
  - Largest beef recall in US history in 2008 (143 million lbs) after videos of down cows going to slaughter were released by US Humane Society

Slide 4

Mad Cow Disease Prevention

- Cow Parts Banned from Human Food Chain

Slide 5

Concerns in the Beef Industry

- Foot and Mouth Disease
  - Virus affecting domesticated animals
  - Rarely fatal, but animals produce less
  - Not a zoonosis
  - Not a human threat, foot and mouth is not related to animal foot and mouth

Slide 6

Foot and Mouth Disease

- First outbreak in Britain in over 20 years was in 2001
- Led to ban of all British exports of meat, milk, dairy, and milk
- 2.7 million sheep and cattle were killed to stop disease spread
Concerns in the Beef Industry

- Hormone Additive Controversy
  - Normally produced in the body to regulate body functions (growth, metabolism, reproduction, etc)
  - Added in feed and through injections to stimulate certain functions
  - Synthetic hormones are approved by the FDA

Concerns in the Swine Industry

- H1N1
  - Highly contagious and cannot be spread through eating pork
  - Spread by close contact with infected animals
  - Outbreak in 2009 – US, swine and humans
  - Spread of the flu in humans to ban pork coming from Mexico and HS
  - Egypt slaughtered 300,000 pigs, although swine flu is spread through eating infected pork
  - Confusion about how H1N1 is spread led World Health Organization to stop using the term “Swine Flu”
Plants

- Sprouts
  - E. coli outbreak, Germany in May 2011
  - Killed 49, over 800 developed life threatening kidney complication
  - Contaminated seeds from Egypt are thought to be the cause.
### Daily Plan

<table>
<thead>
<tr>
<th>Lesson Title:</th>
<th>Agricultural Practices and their Relation to Food Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Title:</td>
<td>Food Safety</td>
</tr>
<tr>
<td>Course:</td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>45 minutes</td>
</tr>
</tbody>
</table>

### Socio-Scientific Issues Instruction – Day 3

#### Materials, Supplies, Equipment, References, and Other Resources:
- Production Practices for Safety Worksheet (classroom set)
- Production Practices for Safety Powerpoint
- Computer linked to a projector
- Classroom set of computers with internet access
- Safety – Who’s Job Is It? Worksheet (classroom set)

#### Agriscience Foundations Standards:
- 2.03 – Evaluate the food safety responsibilities that occur along the food supply chain.
- 6.05 – Demonstrate scientific practices in the management, health, safety, and technology of the animal agriculture industry.
- 4.04 – Identify regulatory agencies that impact agricultural practices.

#### Essential Question:
How is food safety impacted by production practices and animal health?

#### Daily Objectives
1. Identify agricultural organizations’ roles in the production of a safe food supply.
2. Analyze the impact of current agricultural practices on food safety.

### Introduction (Interest Approach)

<table>
<thead>
<tr>
<th>Estimated Time:</th>
<th>5 minutes</th>
</tr>
</thead>
</table>

Have students watch Beef Production Promotional Ad ([http://www.youtube.com/watch?v=4y8WVpbdnb8&feature=related](http://www.youtube.com/watch?v=4y8WVpbdnb8&feature=related)). Note – this video is also located in the dropbox folder if you cannot access youtube.

Through class discussion, create a list of people/organizations responsible for food safety and the actions they take to ensure food safety.
### Learning Activity 1

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Estimated Time: 20 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Broad Content Outline</strong></td>
<td><strong>Guiding questions</strong></td>
</tr>
<tr>
<td>Have students complete the “Production Practices for Safety” Sheet as the teacher uses the powerpoint to inform students of agricultural practices in meat production industries. On the worksheet, the student will list practices that positively impact various industry aspects.</td>
<td>What is the purpose of this practice? Do you feel this practice is necessary? Why/why not?</td>
</tr>
</tbody>
</table>

1. **Beef Industry**
   a. Animal Management
   b. Processing

2. **Swine Industry**
   a. Animal Management
   b. Processing

3. **Poultry Industry**
   a. Animal Management
   b. Processing

4. **Dairy Industry**
   a. Animal Management
   b. Processing

### Learning Activity 2

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Estimated Time: 15 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Broad Content Outline</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
</tbody>
</table>
| Have students get into pairs, each with at least one computer. Using the “Safety – Who’s Job Is It?” Worksheet, student pairs will search the organizations on the sheet to determine how each organization contributes to food safety. | **USDA**
   a. AMS
   b. APHIS
   c. ERS
   d. FSIS
   e. FAS
   f. GIPSA
   g. NASS
   h. NIFA

2. **FDA**

3. **CDC**

4. **EPA**
### Summary (Review)

**Estimated Time: 5 minutes**

When the students are finished with the “Safety – Who’s Job Is It?” sheet, go over answers to ensure theirs are correct.

### Evaluation

Students will be evaluated informally through the guiding questions asked by the teacher and their responses on the “Safety – Who’s Job Is It?” worksheet.

### Items Students Turn In

None.
Production Practices for Safety

Instructions: For each of the aspects of food production concerns listed below, identify specific practices used in different animal industries that positively impact the aspect.

Animal Welfare:
- Beef –
- Swine –
- Poultry –
- Dairy –

Human Health:
- Beef –
- Swine –
- Poultry –
- Dairy –

Food Safety/Quality:
- Beef –
- Swine –
- Poultry –
- Dairy –

Environmental Impact:
- Beef –
- Swine –
- Poultry –
- Dairy –
# Safety – Who’s Job Is It?

**Instructions:** Many organizations are involved in keeping our nation’s food supply safe. Using a computer, search the internet to determine the responsibilities of each of the following organizations in maintaining a safe food supply.

<table>
<thead>
<tr>
<th>Organization</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>__ USDA – Agricultural Marketing Service</td>
<td>A. agency that monitors consumer illness, identifies foods linked with illness, investigates illness outbreaks and cases, and informs public of food safety action.</td>
</tr>
<tr>
<td>__ USDA – Agricultural Research Service</td>
<td>B. administers variety and seed laws, provides voluntary verification services for GM foods.</td>
</tr>
<tr>
<td>__ USDA – Animal and Plant Health Inspection Service</td>
<td>C. federal agency that ensures foods are safe. Responsible for food labeling, safety of all food products except meat and poultry.</td>
</tr>
<tr>
<td>__ USDA – Economic Research Service</td>
<td>D. ensures nation’s supply of meat, poultry, and egg products are safe, wholesome, correctly labeled, and correctly packaged.</td>
</tr>
<tr>
<td>__ USDA – Food Safety and Inspection Service</td>
<td>E. provides inspection and related services on grains, pulses, oilseeds, and processed commodities.</td>
</tr>
<tr>
<td>__ USDA – Foreign Agricultural Service</td>
<td>F. conducts research on economic aspects of using GMOs.</td>
</tr>
<tr>
<td>__ USDA – Grain Inspection, Packers, and Stockyards Administration</td>
<td>F. determines safety and effectiveness of pesticides and establishes tolerance levels for chemical residues on feed crops, raw, and processed foods.</td>
</tr>
<tr>
<td>__ USDA – National Agricultural Statistics Service</td>
<td>G. conducts research in new traits and improving existing livestock. Assesses the safety of biotechnology products.</td>
</tr>
<tr>
<td>__ USDA – National Institute of Food and Agriculture</td>
<td>H. provides information and data on the adoption of biotechnology crops.</td>
</tr>
<tr>
<td>__ Food and Drug Administration</td>
<td>I. supports overseas acceptance of biotechnology and crops that have been reviewed by governmental agencies</td>
</tr>
<tr>
<td>__ Center for Disease Control</td>
<td>J. regulates field testing, interstate movement, and importation of GMOs. Also determines whether a GMO is safe for the environment.</td>
</tr>
<tr>
<td>__ Environmental Protection Agency</td>
<td>K. provides funding and leadership for research in biotechnology and information related to the safety of introducing GMOs to the environment</td>
</tr>
</tbody>
</table>

When you have identified the responsibilities of each organization, describe the step-by-step process (identifying the organizations involved at each step) for GMO development and use that you think a GMO would have to go through in order to be used commercially. Your GMO development list can be listed on the back of this paper.
Slide 1

Agriculture Production Practices

How do practices in the beef industry contribute to or help solve food safety concerns?

Slide 2

The Beef Industry

- Calf Management:
  - Weaned at 400-600 lbs, 6-8 months old
  - Weaning when older is better
  - Forage supplies, weight of calf, breeding efficiency of the cow can affect weaning dates
  - Vaccinated – protects calf health

Slide 3

The Beef Industry

- Calf Management continued:
  - Castrated
  - Injected
  - Implanted
  - Dehorned

Slide 4

The Beef Industry

- Feed Allers:
  - Used in addition to legumes and grains
  - Antimicrobial Drugs – used to keep harmful microbes under control

Slide 5

Growing/Finishing Operations - Feeding Additives

- Beformers
  - Control parasites

Slide 6

Growing/Finishing Operations - Feeding Additives

- Hormones vs Synthetic Hormones:
  - Normally produced in the body to regulate body functions (growth, metabolism, reproduction, etc)
  - Added to stimulate certain functions
  - Synthetic hormones are approved by the FDA for use in feedlots as finishing rations
The Beef Industry

- Processing –
  - Feed additives are removed from feed for a specific amount of time before slaughter
  - Feed is adjusted to condition animals for travel
  - Cattle are moved slowly and quietly to keep animals relaxed and keep meat cuts high quality
  - Trucks are loaded without crowding or underloading to reduce animal injury

The Swine Industry

- Piglet Management, Continued –
  - Tail docking at one day old
    - reduces chance of tail biting
  - Ear notching – identification of individual pigs.
    - More permanent than ear tags
  - Receive dose of long-lasting antibiotic
    - Prevents infection
  - Receive iron injection at 7 days old
    - Sow milk is low in iron (prevents anemia)
  - Boars are castrated at 3-7 days of age
    - reduces stress

The Beef Industry

- Increasing Food Safety –
  - Producers encouraged to attend Beef Quality Assurance Training.
  - Irradiation of ground beef products is done by packers and retailers to kill bacteria (E. coli)
  - Educational efforts encourage consumers to cook hamburger thoroughly, clean surfaces
  - It’s illegal to feel animal products to cattle that may transmit the organism for mad cow disease
  - Country of origin labeling

The Swine Industry

- Increasing Food Safety –
  - Welfare audits - verify that pork was raised under acceptable production conditions
  - Packers require their producers to maintain Pork Quality Assurance certification from National Pork Board
    - provides a voice for producers nationwide and develops promotional/educational materials
  - Producers follow 10 good production practices to ensure pork quality
  - 2002 Farm Bill – Congress mandated country of origin labeling

The Poultry Industry

- Bird Management –
  - Raised in confinement in an open-floor system
  - House is cleaned and disinfected each time a flock leaves, wait one week for new flock to come in
    - Prevents spread of disease between flocks
  - Ventilation
    - Prevents respiratory diseases and reduces odor
Slide 12

The Poultry Industry

- Bird Management, Continued –
  - Chickens may be debeaked (1/3 of upper beak and 1/4 of lower beak is removed)
  - Prevent cannibalism
  - Does not affect growth or health of chickens
  - Hormone implants may be used to produce same results as caponing (surgically castrating males)
  - Causes chickens to produce more tender meat.

Slide 15

The Dairy Industry

- Processing –
  - Cow’s udders are washed
  - Disinfect udder and trigger release of oxytocin, which initiates milk letdown
  - Teats are dipped in iodine
  - Prevents bacterial invasion of udder

Slide 13

The Poultry Industry

- Processing
  - Should not be fed 12 hours before slaughter
  - Avoid overcrowding in delivery coops

Slide 14

The Dairy Industry

- Cow Management –
  - Feeding needs vary by cow status (pregnant, milking, dry, calf, bull)
  - Vitamin and mineral supplementation varies by amount of feed, which varies on lactation period
  - Forages are tested for nutritional quality every 60 days
### Daily Plan

<table>
<thead>
<tr>
<th>Lesson Title:</th>
<th>Improvement Areas in Food Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Title:</td>
<td>Food Safety</td>
</tr>
<tr>
<td>Course:</td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>45 minutes</td>
</tr>
</tbody>
</table>

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

- Public Concerns with the Food Industry Sheets (one set)
- Crayons, markers, other items to promote creativity (optional)

**Agriscience Foundations Standards:**

- 2.03 – Evaluate the food safety responsibilities that occur along the food supply chain.
- 6.05 – Demonstrate scientific practices in the management, health, safety, and technology of the animal agriculture industry.
- 4.04 – Identify regulatory agencies that impact agricultural practices.

**Essential Question:**

How can the animal and food industries improve food safety?

**Daily Objectives**

1. Compare current agricultural practices and consumer concerns to determine areas of improvement in food safety.
2. Evaluate the potential benefits and drawbacks of possible solutions to current food safety issues.

---

### Introduction (Interest Approach)

**Estimated Time:** 10 minutes

Hold a brief class discussion about whether the students feel the public concerns with food safety warrant the development and production of GMOs.

**Guiding questions** – Do you feel GMOs should be developed and produced? What public concerns with food safety do you think the GMOs alleviate? Are any new concerns developed with the development of GMOs? Are any public concerns alleviated with methods other than GMO development?
# Learning Activity 1

**Estimated Time: 20 minutes**

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Brief Content Outline</th>
</tr>
</thead>
</table>
| Divide students into eight groups. Give each group one of the attached “Public Concerns with the Food Industry” sheets. The groups should develop a list of current solutions that the food industry is employing in response to the public concerns. The solutions can be written in the appropriate spaces on the sheets (if preferred, you can supply crayons or markers and direct students to draw pictures representing the current solutions or develop “commercials” to advertise their solutions to the problem). Have each group present the concerns listed on the sheet and the solutions they feel are being used to address those concerns. If students do not list the concerns on the content outline, question them about whether they think those address the concerns as well. Encourage students to question one another in this manner as well. | 1. Food Quality  
   a. Public Concerns  
   b. Current Solutions  
2. Food Safety  
   a. Public Concerns  
   b. Current Solutions  
3. Economic Impacts  
   a. Public Concerns  
   b. Current Solutions  
4. Environmental Impacts  
   a. Public Concerns  
   b. Current Solutions  
5. Human Health  
   a. Public Concerns  
   b. Current Solutions  
6. Plant and Animal Industry  
   a. Public Concerns  
   b. Current Solutions  
7. Animal Welfare  
   a. Public Concerns  
   b. Current Solutions  
8. Ethics  
   a. Public Concerns  
   b. Current Solutions |
<table>
<thead>
<tr>
<th><strong>Summary (Review)</strong></th>
<th><strong>Estimated Time: 15 minutes</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Using their notes from the week, including biotechnological advancements and their benefits and drawbacks, historical events that have led consumers to elicit concerns regarding food safety, agricultural practices addressing food safety, governmental organizations involved in food safety, and current solutions to public food safety concerns, have students individually create newspaper articles that convince readers that the food supply is safe or should be a cause of concern for the public. These should be turned in as students leave.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Evaluation</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will turn in their newspaper articles and will be evaluated through additional questions asked during their presentations.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Items Students Turn In</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Newspaper articles</td>
</tr>
</tbody>
</table>
Public Concerns with the Food Industry

Food Quality

Public Concerns:
- Inconsistency with product quality
- Cost versus quality
- Shelf life of products

Current Solutions:
Public Concerns with the Food Industry
Food Safety

Public Concerns:
- Contamination through processing
- Allergens
- Lack of consistent regulation
- Bioterrorism
- Lack of knowledge of GMO impacts

Current Solutions:
Public Concerns with the Food Industry  
Economic Impacts

Public Concerns:
- High cost of quality foods
- World hunger

Current Solutions:
Public Concerns with the Food Industry
Environmental Impacts

Public Concerns:
- Agriculture industry’s impact on water, soil, and air quality

Current Solutions:
Public Concerns with the Food Industry
Human Health

Public Concerns:
- Food safety recalls from food infected with diseases
- Poor diets that are high in fat and low in nutrition lead to diseases
- Increasing prevalence of food allergies among children

Current Solutions:
Public Concerns with the Food Industry
Plant and Animal Industries

Public Concerns:
- Larger farms push out smaller farms
- Growing world population
- Public perception of food production practices

Current Solutions:
Public Concerns with the Food Industry
Animal Welfare

Public Concerns:
- public perception of food production practices related to treatment of animals

Current Solutions:
Public Concerns with the Food Industry
Ethics

Public Concerns:
- some disagree with the slaughtering of animals for human consumption

Current Solutions:
<table>
<thead>
<tr>
<th>Daily Plan</th>
<th>Socio-Scientific Issues Instruction – Day 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lesson Title:</strong></td>
<td>Food Safety Assessment</td>
</tr>
<tr>
<td><strong>Unit Title:</strong></td>
<td>Food Safety</td>
</tr>
<tr>
<td><strong>Course:</strong></td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>45 minutes</td>
</tr>
</tbody>
</table>

**Materials, Supplies, Equipment, References, and Other Resources:**
- Food Safety Posttest (classroom set)
- Computer linked to a projector and the internet

**Agriscience Foundations Standards:**
- 3.08 – Evaluate advances in biotechnology that impact agriculture (e.g. transgenic crops, biological controls, etc.).
- 1.04 – Examine the role of the agricultural industry in the interaction of population, food, energy, and the environment.
- 3.06 – Interpret, analyze, and report data.
- 2.03 – Evaluate the food safety responsibilities that occur along the food supply chain.
- 6.05 – Demonstrate scientific practices in the management, health, safety, and technology of the animal agriculture industry.
- 4.04 – Identify regulatory agencies that impact agricultural practices.

**Essential Question:**
How does the agricultural industry address public concerns of food safety?

**Daily Objectives**
1. Display knowledge regarding agricultural industry practices and public concerns of food safety.
2. Evaluate the benefits and drawbacks of cultured meat on food safety.
### Introduction (Interest Approach) | Estimated Time: 5 minutes
---

Explain to students that they will be taking the Food Safety Posttest.

### Learning Activity 1 | Estimated Time: 10 minutes

**Instructor Directions / Materials**

Students will complete the Food Safety Posttest. Standard testing procedures should be enforced.
Tests should be turned in upon completion.

### Learning Activity 2 | Estimated Time: 25 minutes

**Instructor Directions / Materials**

Split students into two groups – one advocating for the production of cultured meat and one opposing the production of cultured meat (they don’t have to really feel this way, but should be prepared to defend the assigned position regardless of their personal viewpoints).

Have students watch the news clip regarding people’s viewpoints of genetically engineered meat ([http://www.youtube.com/watch?v=W-Ou5TISemU&feature=related](http://www.youtube.com/watch?v=W-Ou5TISemU&feature=related)). **Note – this video is also available in the dropbox folder if you do not have access to youtube.** Tell students to pay particular attention to the comments made regarding aspects of food safety.

Hold a brief debate between the two student groups by having students line up on “sides”, facing a member of the opposing side.
Designate one side to go first, and have the first student provide a statement the supports the side’s viewpoint. Statement requirements include:
- Must support viewpoint of assigned side
- Must focus on the food safety aspect of the controversy

The opposing side member facing this first student will offer a rebuttal with a statement (also following the above requirements) that either refutes the previous student’s comment or offers a new statement. Students will offer statements, alternating turns on each side, down the line until all students have provided a statement.
<table>
<thead>
<tr>
<th><strong>Summary (Review)</strong></th>
<th><strong>Estimated Time: 5 minutes</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>As a class, have a brief discussion about which side students feel “won” the debate and the aspects of the debate that they feel caused that side to win.</td>
<td></td>
</tr>
</tbody>
</table>

**Evaluation**

Students will submit their Food Safety Posttest.

**Items Students Turn In**

Food Safety Posttest
<table>
<thead>
<tr>
<th>Daily Plan</th>
<th>Socio-Scientific Issues Instruction – Day 6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lesson Title:</strong></td>
<td>Animal Production and the Economy</td>
</tr>
<tr>
<td><strong>Unit Title:</strong></td>
<td>Economic Impact</td>
</tr>
<tr>
<td><strong>Course:</strong></td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>45 minutes</td>
</tr>
</tbody>
</table>

**Materials, Supplies, Equipment, References, and Other Resources:**
- Economic Impact Pretest (classroom set)
- Classroom set of computers with internet access
- List of Economic Impacts Websites (one per group, or post on projector) *Note – teacher is responsible for checking each website for inappropriate content before class*

**Agriscience Foundations Standards:**
1.02 – Analyze the impact of agriculture on the local, state, national, and global economy.
6.01 – Explain the economic importance of animals and the products obtained from animals.
3.06 – Interpret, analyze, and report data.

**Essential Question:**
How does the agricultural industry contribute to our economy?

**Daily Objectives**
1. Explain the economic importance of meat production.
2. Identify aspects that determine credibility of written sources.

**Introduction (Interest Approach)**
- Estimated Time: 15 minutes

Students will take the Economic Impacts Pretest.
### Learning Activity 1

**Estimated Time: 20 minutes**

#### Instructor Directions / Materials

Arrange students into groups of 2. Ask the groups to develop a well-supported answer to the following questions:

Does the current animal production industry positively or negatively impact the nation’s economy? Would the use of cultured meat alleviate or cause economic problems?

Give each student group 1 or 2 computers, depending on computer availability. Have students search the list of economic impacts websites to develop a multi-point argument supporting their answer. During their data collection, students should also develop a list of criteria they used in determining whether the websites’ information was credible or not. *Note – websites are associated with organizations, and may be blocked from school servers. Instruct students to search for other resources if necessary. Further, some websites may contain offensive or controversial content due to the controversial nature of the subject. Teachers should view all websites before class to ensure that all content is appropriate for the class.*

Explain to students that they will be presenting their arguments and their lists of criteria for credibility during the next lesson.

#### Summary (Review)

**Estimated Time: 10 minutes**

Using their credibility criteria lists, have student groups evaluate the credibility of at least one website opposing their viewpoint. Reasons for whether the website is credible or not should be written at the bottom of their lists of credibility criteria to be used in the next class.

#### Evaluation

Students will present their arguments and their lists of criteria for credibility, as well evaluate the credibility of other groups’ arguments, during the following class.

#### Items Students Turn In

- Economic Impact Pretest
Economic Impact Websites

- Meat Fuels America: [www.meatfuelsamerica.com](http://www.meatfuelsamerica.com)
  - (click on “Business Economics”)
- New Harvest: [http://www.new-harvest.org](http://www.new-harvest.org)
- Why Cultured Meat:
  - [http://www.whyculturedmeat.org](http://www.whyculturedmeat.org)
- The In Vitro Meat Consortium: [http://invitromeat.org](http://invitromeat.org)
### Daily Plan

<table>
<thead>
<tr>
<th><strong>Lesson Title:</strong></th>
<th>Debating the Economic Impact of Animal Production</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit Title:</strong></td>
<td>Economic Impacts</td>
</tr>
<tr>
<td><strong>Course:</strong></td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>45 minutes</td>
</tr>
</tbody>
</table>

**Materials, Supplies, Equipment, References, and Other Resources:**
- Criteria for Credibility Sheet (classroom set)
- Criteria for Credibility powerpoint
- Economic Impact Reflection Question (classroom set)

**Agriscience Foundations Standards:**
1.02 – Analyze the impact of agriculture on the local, state, national, and global economy.

6.01 – Explain the economic importance of animals and the products obtained from animals.

3.06 – Interpret, analyze, and report data.

**Essential Question:**
How does the agricultural industry contribute to our economy?

**Daily Objectives**
1. Evaluate the trustworthiness and credibility of information sources.
2. Develop an argument defending a specific viewpoint regarding the economic impact of the animal production industry.
### Introduction (Interest Approach)  
**Estimated Time: 10 minutes**

Hand out the “Criteria for Credibility” sheet. In their groups from the previous class, have students reflect on their use of the included aspects of credibility. Reflections should be written in the appropriate place on the sheet. *Note – each student should complete his/her own reflection sheet.*

### Learning Activity 1  
**Estimated Time: 15 minutes**

**Instructor Directions / Materials**

Through lecture, the teacher will use the powerpoint to guide students through the criteria for evaluating sources. *Note – the powerpoint evaluates pieces of the Dihyrogen Monoxide website for credibility, and should be used to supplement discussion guided by the Criteria for Credibility sheet.* During this time, students should be encouraged to discuss how they found or used aspects of criteria to evaluate their sources according to their reflections written on their sheet. Students should also write additional notes from the discussion on their sheets.

**Guiding questions – How did you use this piece of criteria? Was the website you evaluated credible based on this piece of criteria? Did you find anything that told you this piece of criteria was lacking? Where do you think you could find this on a website? Did you have this piece of criteria on your list from yesterday? Why or why not?**

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Brief Content Outline</th>
</tr>
</thead>
</table>
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   a. Authority of the author/publisher/speaker  
   b. Objectivity of the author  
   c. Quality of the work  
   d. Coverage of the work  
   e. Currency of the work |
### Learning Activity 2

**Estimated Time: 15 minutes**

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Brief Content Outline</th>
</tr>
</thead>
</table>
| Student groups will present their arguments developed yesterday. During their presentations, they should include the following:  
  - Their viewpoint  
  - Supporting evidence from the websites related to their viewpoint (not related to the credibility of the website)  
  - The websites they got their supporting evidence from  

**Note** - *If time is limited, the teacher should select a number of groups to present, either voluntarily or through teacher selection. If this is done, groups should have different viewpoints if possible.*  

During the presentations, students should be instructed to consider the evidence being presented and evaluate its credibility according to their current knowledge on the subject. The teacher should also ask students with opposing viewpoints whether they evaluated the current presenter's websites and evidence they found related to the websites' credibility.

### Summary (Review)

**Estimated Time: 5 minutes**

Students should respond individually to the Economic Impact Reflection Question and turn in their responses.

### Evaluation

Students will be evaluated through classroom discussion during presentations and through their reflection responses.

### Items Students Turn In

- Criteria for Credibility sheet (optional – should be returned to students if collected)
- Economic Impact Reflection Question
**Criteria for Credibility**

**Instructions:** Using the criteria listed on the left side of the page, reflect on how you used (or did not use) each piece of criteria when you evaluated website credibility yesterday. Include examples in your reflections from the website you evaluated. Be sure to flip the page over – there is a back!

<table>
<thead>
<tr>
<th>Credibility Criteria</th>
<th>Example</th>
<th>Student Reflection of Use</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Authority of author/publisher</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who is the author?</td>
<td>Organization, one person, university, etc.</td>
<td></td>
</tr>
<tr>
<td>What are the author’s credentials?</td>
<td>Educational degrees, institutional affiliation, employment experience, past writings</td>
<td></td>
</tr>
<tr>
<td>What is the author’s reputation?</td>
<td>Cited in articles on the topic, what you know from informal conversation or hearsay</td>
<td></td>
</tr>
<tr>
<td>Who is the publisher?</td>
<td>.edu, .gov, .org? Known for scholarly publications, basic values and goals, beliefs or goals of the organization</td>
<td></td>
</tr>
</tbody>
</table>

**Class Notes regarding Authority of Author/Publisher:**

<table>
<thead>
<tr>
<th>Objectivity of author</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Goals of the publication?</td>
<td>Inform, educate, explain, persuade? Try to sell something? Does the author rant or rave?</td>
<td></td>
</tr>
<tr>
<td>Does the author exhibit a particular bias?</td>
<td>Commitment to a point of view, acknowledgement of bias, presents both sides or only one side of an issue, language free of emotion-arousing words and biases</td>
<td></td>
</tr>
<tr>
<td>Does the information appear to be valid and well-researched?</td>
<td>Reasonable assumptions and conclusions, supported by evidence,</td>
<td></td>
</tr>
<tr>
<td>Class Notes regarding Author Objectivity:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------------</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quality of work</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the information well organized?</td>
<td>Logical structure, clear main points, text flows well, good grammar</td>
</tr>
<tr>
<td>Are graphics professional and appropriate?</td>
<td>Professional layout, website is error free</td>
</tr>
<tr>
<td>Is information complete and accurate?</td>
<td>Facts and results agree with your knowledge on the subject and with other things you have read or learned, sources are documented</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class Notes regarding Quality of Work:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Coverage of work</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the work use other sources?</td>
<td>Includes references</td>
</tr>
<tr>
<td>Have you found enough information to support your argument</td>
<td>Gaps in your argument and evidence (facts, statistics, etc.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class Notes regarding Coverage of Work:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Currency of work</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>When was it published or last edited?</td>
<td>Website maintained</td>
</tr>
<tr>
<td>Does the topic require current information?</td>
<td>Information may change based on new developments</td>
</tr>
<tr>
<td>Has the source been revised or updated?</td>
<td>Updates, recent news brief, etc.</td>
</tr>
</tbody>
</table>

| Class Notes regarding Currency of Work: |
Economic Impact Reflection Question

Consider on your work over the past two days, the information you viewed on the websites, and the information you learned in student presentations. Based on these, what is your opinion regarding the following two questions:

Does the current animal production industry positively or negatively impact the nation’s economy?

Would the use of cultured meat alleviate or cause economic problems?

Please support your opinions with appropriate evidence.
Evaluating Websites

Criteria for Credibility

Authority of Author/Publisher
- with organization, university, or company
- Copyright – Tom Way
- Author's reputation
- Creator of DHMO has chapter in South Park book

Publisher
- .edu, .gov, .org, .net

Specializations
- Values, goals, mission
- Author's credentials?
- Author's reputation/specialization?

Anyone can create a .org website
Selling something – is goal to educate/inform?

You Decide: Real or Fake Website?
Ban Dihydrogen Monoxide!
Dihydrogen Monoxide: H2O
Website asks you to ban...WATER!
Answer: FAKE!

Moral of the story – every information giving source (website, person, book, newspaper, etc.) should be evaluated for credibility

Considerations when Evaluating Credibility
- Authority of author/publisher
- Objectivity of author
- Quality of the work
- Coverage of the work
- Currency of the work

Let’s evaluate the Dihydrogen Monoxide website according to these criteria...

Quality of the Work
- Overall inclusion of argument is unprofessional
- Uses copyrighted image without permission
- Twists words of Hoard’s Dairyman editor to make it seem like a cover-up

Author Objectivity
- No sources cited.
- Although, none of these are wrong!
- Commits to one-sided viewpoint
- Emotional language
- Facts lead to inaccurate/illogical conclusions

Author’s credentials?

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Author Objectivity
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- Although, none of these are wrong!
- Commits to one-sided viewpoint
- Emotional language
- Facts lead to inaccurate/illogical conclusions

Author’s credentials?

Coverage of the Work

All studies were surveys about the banning of DHMO, conducted by high school students.

What were students really testing—whether DHMO should be banned, or whether students will support something based on the message about it?

Currency of the Work

Website update is the same as today’s date, every day.

Coincidence?

Student Presentations

What is your viewpoint on yesterday’s questions, based on the websites you investigated?
### Daily Plan

<table>
<thead>
<tr>
<th>Lesson Title:</th>
<th>Products Impacting the US Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Title:</td>
<td>Economic Impact</td>
</tr>
<tr>
<td>Course:</td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>45 minutes</td>
</tr>
</tbody>
</table>

### Materials, Supplies, Equipment, References, and Other Resources:

- Agricultural Commodities powerpoint

### Agriscience Foundations Standards:

1.02 – Analyze the impact of agriculture on the local, state, national, and global economy.

6.01 – Explain the economic importance of animals and the products obtained from animals.

6.07 – Investigate the nature and properties of food, fiber, and by-products from animals.

3.06 – Interpret, analyze, and report data.

### Essential Question:

How does the agricultural industry contribute to our economy?

### Daily Objectives

1. Predict the role of the United States in the global agricultural market.
2. Identify agricultural products that contribute to local, state, national, and global economies.
3. Describe the global relationship of importers and exporters of agricultural products.

### Introduction (Interest Approach)

<table>
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<th>Estimated Time: 5 minutes</th>
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On a sheet of paper, have each student list their 5 favorite non-processed foods. Then, have the students predict and write down the top countries they think are responsible for producing the most of each of those products.
<table>
<thead>
<tr>
<th>Learning Activity 1</th>
<th>Estimated Time: 15 minutes</th>
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</thead>
<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>The teacher should access the FAO’s Division of Statistics’ webpage (<a href="http://www.fao.org/es/ess/top/country.html?lang=en&amp;country=231&amp;year=2005">http://www.fao.org/es/ess/top/country.html?lang=en&amp;country=231&amp;year=2005</a>) on the computer projector for the class to see. Then the teacher should ask students about their favorite foods and what their predictions were. Using the “Countries by Commodity” link on the left side of the page, the teacher should look up the product with the class to determine the top producers of that product (note: the most current year’s data is from 2005). If the US is not #1 for a product, show the class where the US ranks for that product.</td>
<td>During this activity, class discussion should focus on the students’ predictions and reactions to the top countries for their favorite products. <strong>Guiding questions</strong> – What is your favorite agricultural product? Which country do you think is responsible for the most production? Where do you think the US falls in production for that product? Why do you think that country is ranked so high for that product? Why do you think the US is/is not ranked #1 for that product?</td>
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<tr>
<th>Learning Activity 2</th>
<th>Estimated Time: 15 minutes</th>
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<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>Following the Agricultural Commodities powerpoint, the teacher should lecture about the top agricultural commodities for the US and Florida. During the lecture, the students should take notes and consider how the mass production of cultured meat would impact the demand and production for the US top commodities.</td>
<td><strong>Guiding questions</strong> – Why is the US capable of being a top producer of this commodity? Why are these items Florida’s top commodities? How would the production of cultured meat impact the need for these products? How do you think that would impact other aspects of the economy? 1. US Ranking in World Production (Food and Agricultural Organization of the United Nations, 2005) 2. US’s most important agricultural commodities (Food and Agricultural Organization of the United Nations, 2005) 3. Florida’s top commodities (USDA, 2009) 4. Florida’s top exports (USDA, 2009) 5. Florida’s top counties in ag. sales (USDA, 2007)</td>
</tr>
<tr>
<td>Summary (Review)</td>
<td>Estimated Time: 10 minutes</td>
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<tr>
<td>Instruct students to create a meal that utilizes the greatest number of top US agricultural products. The meal should be complete, and may use products from other countries when necessary. Students should ask the teacher what country is the top producer of an ingredient if the US is not #1, and the teacher can look it up on the previously used website. If there is time, the class can compete for the student that creates a realistic dish with the most US ingredients.</td>
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<table>
<thead>
<tr>
<th>Evaluation</th>
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<tbody>
<tr>
<td>Students will be evaluated formatively through in class questioning and the meal creation competition.</td>
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</table>

<table>
<thead>
<tr>
<th>Items Students Turn In</th>
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<tbody>
<tr>
<td>None.</td>
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<tr>
<td>Daily Plan</td>
<td>Socio-Scientific Issues Instruction – Day 9</td>
</tr>
<tr>
<td>------------</td>
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</tr>
<tr>
<td><strong>Lesson Title:</strong></td>
<td>Increasing the Economic Value of Animal Production</td>
</tr>
<tr>
<td><strong>Unit Title:</strong></td>
<td>Economic Impact</td>
</tr>
<tr>
<td><strong>Course:</strong></td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>45 minutes</td>
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</tbody>
</table>

**Materials, Supplies, Equipment, References, and Other Resources:**
One agricultural commodity and one value-added product with a higher unit price than the commodity
Presentation materials (based on teacher’s preferences)
Increasing Agricultural Profit: Value-Added and By-Products (classroom set)

**National AFNR Standards:**
1.02 – Analyze the impact of agriculture on the local, state, national, and global economy.
6.01 – Explain the economic importance of animals and the products obtained from animals.
6.07 – Investigate the nature and properties of food, fiber, and by-products from animals.
6.08 – Explore career opportunities in animal science.

**Essential Question:**
How does the agricultural industry contribute to our economy?

**Daily Objectives**
1. Identify agricultural products that contribute to local, state, national, and global economies, including byproducts and value-added products.
2. Explain how the use of certain value-added and by-products can add economic value to traditional agricultural products.
3. Predict how the use of cultured meat could impact the agricultural industry’s value-added and by-products.

**Introduction (Interest Approach)**
Bring in one agricultural commodity and a related value-added product (milk and ice cream, yogurt, or cheese; a whole chicken and frozen, breaded chicken tenders; a whole grapefruit and sliced, packaged grapefruit pieces, etc.). *Note: make sure that the value-added product has a higher unit price than the less processed product.* Tell the students how much each item costs and the amount of each item, and ask them to calculate the unit price of each item. Then, hold a brief discussion about why they think the value-added item has a higher unit price.

*Guiding questions – Why do you think the value-added item has a higher unit price? Who do you think gets the extra money? How do you think the farmer can get more profit out of their products?*
<table>
<thead>
<tr>
<th>Learning Activity 1</th>
<th>Estimated Time: 30 minutes</th>
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<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
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</table>
| Explain that by-products are another method of profit growth for producers. Arrange students in groups of 2-3 and assign each group a type of farm (a variety of plant and animal production businesses should be assigned, and these can be real local businesses if possible). Give each student a copy of the Increasing Agricultural Profit: Value-Added and By-Products sheet. Have the students create a plan for increased profit for the producers based on the addition of value-added and by-products possible for the farm to produce. Based on the teacher’s and students’ preference, the students can be provided with materials to display their plans on posters, with pictures, or a variety of other creative ways. During this time of plan development, the teacher should walk around and discuss the value-added and by-products content with the groups.  

*Guiding questions – What makes this a value-added product or by-product? How do you think that product will add to the producer’s profit? Are there any additional risks the farmer takes on by producing that product? What about this product that you don’t have listed?*

Students should then present their plans to the class. The class should be encouraged to offer other ideas about products and ask questions similar to the guiding questions above. | 4. Value-added agriculture - any activity an agricultural producer performs outside of traditional commodity production to receive a higher return per unit of commodity sold. The value of the product increases per unit sold.  
   a. The producer does more processing in-house  
   b. The producer markets directly to consumers  
   c. The producer engages in agritourism and entertainment agriculture  
   d. Benefits – could result in more profits for producers  
   e. Drawbacks – increases risk for producers, because it involves more labor/production not typically performed by the producer  
   f. Examples of Value Added Businesses in Florida:  
   5. Agricultural by-products – items created as a result of food production  
   a. Adds value to waste  
   b. Examples of by-products  
      i. Stem and leaf waste  
      ii. Cleaning and washing wastes  
      iii. Sorting waste and culls  
      iv. Peeling and coring wastes  
      v. Fruit pit waste  
      vi. Milling waste  
      vii. By-products of the Meat Industry  
         1. Edible by-products  
         2. Inedible by-products |
Using a think-pair-share technique, ask students to consider how the supply and demand of value-added and by-products might be altered by the production of cultured meat.

*Guiding questions – Would all current products still be able to be produced? Could new products be developed? What do you think demand for value-added and by-products would do if the supply was altered?*

**Evaluation**

Students will be evaluated based on their presentations of value-added products and by-products.

**Items Students Turn In**

None.
Increasing Agricultural Profit: Value-Added and By-Products

What is value-added agriculture?
Any activity an agricultural producer performs outside of traditional commodity production to receive a higher return per unit of commodity sold. The value of the product increases per unit sold.

What are some practices that add value to products?
- The producer does more processing in-house, like when a dairy makes cheese or ice cream.
- The producer markets directly to consumers, like when a farmer’s stand sells off the farm.
- The producer engages in agritourism and entertainment agriculture, like when a farm has hayrides, petting zoos, or pick-your-own fields.

What is the benefit of value-added agriculture?
Value-added products could lead to more profit for the producers.

Are there any drawbacks to value-added agriculture?
Producers have to supply more labor and production, sometimes requiring more equipment, which requires more money. Therefore, there is greater risk for producing value-added products.

What are some value-added businesses in Florida?
- Wineries using tropical fruits.
- Tropical fruit ice cream and milk shakes.
- Jams and jellies.
- Fruit baskets.
- Bed and Breakfasts.
- Agritourism (e.g., farm tours, festivals, picnics, catered parties).
- Bird watching.
- Fishing.
- Spice parks.
- Alligator farms.
- Direct sales to restaurants and retailers.
- Farmers markets.
- U-pick, or pick-your-own.
- Roadside markets.

Are there any drawbacks to value-added agriculture?
Producers have to supply more labor and production, sometimes requiring more equipment, which requires more money. Therefore, there is greater risk for producing value-added products.

What are agricultural by-products?
Items created as a result of food production. Using by-products adds value to items that would otherwise be waste.

(Over)
What are some examples of by-products?

- Stem and leaf waste – (from production of vegetables, fruits, etc) can be used to produce energy (biogas or electricity), banana stem waste is used to make handmade paper (value-added byproduct)
- Cleaning and washing wastes – usually high moisture, low organic material. Lactic acid produced in meat packing plants from fermentation – can be used in animal feeds or as a flavoring and preserving agent
- Sorting waste and culls – culled apples make apple juice, others are used for animal feed, lotions, vitamins, etc.
- Peeling and coring wastes - orange peels can be made into citrus oil and molasses, papaya makes chewing gum, medicine, toothpaste, and meat tenderizers, others make natural sweeteners
- Fruit pit waste – can be burned as a fuel, grapefruit seed extract can be turned into emergency water treatment product
- Milling waste – wheat byproducts make flour supplements, corn byproducts make corn syrup, starches, ethanol as a gas additive
- By-products of the Meat Industry
  - Edible by-products
    - Unused parts – variety meat (scapple, spam, souse, loaves, etc.)
    - Blood – component in sausage
    - Stomach – sausage container, component of cheese-making process
    - Bones – gelatin in ice cream and jellied food products
    - Fats – shortening, candies, chewing gum
    - Intestines – sausage casings
  - Inedible by-products
    - Hide – leather goods, upholstery
    - Pelts – wool, ointments (lanolin)
    - Fats – industrial oils, lubricants, animal feeds
    - Bones – glue, fertilizer, leather preparation
    - Cattle feet – lubricants, neatsfoot oil (leather preparations)
    - Glands – medicines
      - Ovaries make estrogen and progesterone
      - Pancreas makes insulin
    - Lungs – pet foods
    - Intestines – surgical sutures and condoms
    - Liver – cortisone
    - Spinal cord – processed into vitamin D
    - Fetal calf blood – used for cancer and AIDS research
    - Aorta valves – replacement in human heart valves
    - Fetal pigs – teaching biology through dissection
Introduction (Interest Approach) | Estimated Time: 5 minutes
--- | ---
Have students watch the “Milk Rap” (http://www.youtube.com/watch?v=vwB4DbKWrhU). After they watch, ask them how they think different populations of people impact the demand of different agricultural products. Hold a brief class discussion exploring their perceptions of the link between populations and agricultural demand trends.

Guiding questions – Who does the milk rap try to attract to drinking milk? Who normally consumes milk? What other products are dependent on certain populations? What population factors do you think impact the demand of certain foods? What products do you think your population (age range) impacts?
### Learning Activity 1

**Estimated Time: 15 minutes**

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Brief Content Outline</th>
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</thead>
</table>
| Explain to students that they will be determining the impact that a specific population has on the demand of agricultural products. They will be conducting “field tests” to answer this question, and should consider what products they might impact based on the background information included in the lecture and powerpoint. | 1. Demographic Projections between 2002 and 2020 (USDA)  
2. Previous trends  
3. USDA’s Projected Trends (2002-2020) |
<p>| Then, the teacher should lecture to the students using the Agricultural Trends powerpoint, giving them a background for how different populations have been seen to impact agricultural products. |  |
| Students should take notes on the lecture to help guide them in their field test development. |  |</p>
<table>
<thead>
<tr>
<th><strong>Summary (Review)</strong></th>
<th><strong>Estimated Time: 5 minutes</strong></th>
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<tbody>
<tr>
<td>Explain and discuss with students the homework required on the worksheet. Students will be conducting their field tests between the end of this class and the beginning of the next class at a place they have access to. The group partners will be collecting data separately and combining their data during the next class. Data collection will typically be either through observation (tally marks for a specified amount of time) at a specific place and on a specific population (ex. – number of ears of corn bought by middle-aged women at Walmart between 5 and 6 pm) or through a survey (ex. – students in the lunchroom answer questionnaires about their eating preferences). All students should arrive to class the next day with data collected based on the specifications set by the group.</td>
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<tr>
<th><strong>Evaluation</strong></th>
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<tbody>
<tr>
<td>Students will be evaluated through their data collection and reporting during the following class.</td>
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<thead>
<tr>
<th><strong>Items Students Turn In</strong></th>
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<tr>
<td>None.</td>
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</table>
Agricultural Trends Field Test

Names of Group Members

Instructions: You will design an experiment to test a hypothesis you have regarding populations’ impact on the food industry based on their buying preferences. Each group member completes a separate sheet.

1. Population Selected:

*Select a population you have access to and have an idea about what their buying preferences might be. Examples: Middle school students, high school students, agriculture students, teachers, mothers shopping after work, men shopping alone, etc.*

2. Food Product Selected:

*Select a specific food product (canned peaches) or area of general food products (fresh vegetables).*

3. Hypothesis:

*Explain what you think you will observe or find out, and why you think this. Example: I think that my population (middle school students) will consume more chocolate milk than regular milk because they prefer sugary foods to those that are nutritious.*

4. Setting Selected:

*Explain where you will go to collect data. Examples: cafeteria, Walmart, McDonalds, etc.*

5. Data Collection:

*Explain how you will collect data. Examples: I will ask students to fill out a survey that I will create. I will sit in McDonald’s and tally the number of people that order milkshakes. I will sit in the cafeteria and observe the number of students who get pizza. I will stand in Walmart and observe the number of fresh vegetables that middle-aged women put in their carts.*
6. **Limiting the Data:**

*Explain how you will standardize the data collection procedures between you and your partner. This should include collecting data for a specific amount of time, at a specific time of day, and/or from a specific number of people (survey).*

7. Below, create the data collection sheet or survey you will be using. A data collection sheet involving observation should include a table format with areas to tally needed data. A survey should include multiple questions and closed-ended answer choices (multiple choices, circling a response from strongly disagree to strongly agree, etc.) and should not include open-ended questions (participants should not have to create their own answer). Surveys may be asked verbally (like a short interview) and the researcher (you) can tally data based on their answers instead of printing out survey sheets for people to write on. If you decide to tally verbal responses, you should include boxes on your sheet for you to do so.
AGRICULTURAL TRENDS
How different populations impact food demand

Previous Trends – Consumer Budgets
• Food budgets decreased by 2.8% between 1970 and 1995.
• 2009 – 4.5% of budget spent on food.

USDA’s Demographic Projections (2002-2020)
• Nation will become more racially diverse
• Proportion of population age 20-34 will decrease, while those 45-74 will increase
• People will take on food habits of age group they enter

Previous Trends – Consumer Eating Habits
• Food away from home has increased (48% of food budget in 2009), over 1/3 going to fast food
• Average US Adult buys a restaurant snack or meal 5.8 times per week
• 1970-1995 – consumption of fruits, vegetables, grains, fruits, fats, oils, and sweets increased while meat and dairy has remained constant

Previous Trends – Consumer Demand
• Consumers have become more convenience-oriented, health conscious, and they expect food to be safe to eat, eat more processed foods, and purchase from larger supermarkets
• Increase in local farmers’ markets
• Increase in demand for fresh fruits and vegetables
• Increase in sales of environmentally friendly and locally grown products

Previous Trends – Consumer Meat Eating Habits
• Beef consumption declined 15%
• Pork consumption declined 13%
• Chicken consumption more than doubled
• Turkey consumption grew 127% – Due to changes in prices, income, preferences, product development
• Shell egg consumption decreased 37%, processed egg consumption increased 88% – Due to health, taste, and cooking style

Assumes the following:
- As people increase in age, they will take on the eating habits of the new age group.
- Incomes will increase by 1% each year.

Do you think these assumptions are accurate?

Projected Trends – Increasing Incomes
- Food budgets will increase, with away-from-home consumption increasing more than at-home.
  - At-home increases: fruits, vegetables, fish, prepared foods, sugar, beef, eggs, poultry.
  - At-home decreases: desserts, pork.
- As income increases, consumers will want more quality food over quantity, including value-added products, increased diversity in products, food with greater convenience, or those that align with environmental and animal welfare efforts.
- Overall beef consumption will decrease.
  - Due to health education, income growth, aging population, and preference for poultry and fish.
  - Money spent on beef will increase.
    - Due to purchasing higher quality cuts and grades, as well as semi-prepared beef meals.

Projected Trends – Aged Populations
- Decrease: fried potatoes, cheese, sugar, beef, poultry.
- Increase: other types of potatoes, fruits, fish, and eggs.

Projected Trends – More Racially Diverse Populations
- Decrease: dairy products, certain types of potatoes.
- Increase: fruits, nuts, seeds, eggs, poultry, fish, beef, poultry.

Conduct your own Field Test!
<table>
<thead>
<tr>
<th>Daily Plan</th>
<th>Socio-Scientific Issues Instruction – Day 11</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lesson Title:</strong></td>
<td>Agricultural Demands of Consumer Populations – Part II</td>
</tr>
<tr>
<td><strong>Unit Title:</strong></td>
<td>Economic Impacts</td>
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<tr>
<td><strong>Course:</strong></td>
<td>Agriscience Foundations</td>
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<tr>
<td><strong>Estimated Time:</strong></td>
<td>45 minutes</td>
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</tbody>
</table>

**Materials, Supplies, Equipment, References, and Other Resources:**
- Classroom set of computers or classroom set of graph paper
- Student data collected for homework from the previous class

**Agriscience Foundations Standards:**
- 1.02 – Analyze the impact of agriculture on the local, state, national, and global economy.
- 6.01 – Explain the economic importance of animals and the products obtained from animals.
- 3.06 – Interpret, analyze, and report data.

**Essential Question:**
How does the agricultural industry contribute to our economy?

**Daily Objectives**
1. Identify recent consumer trends in agricultural demand based on specific populations.
2. Analyze the impact of specific populations on certain agricultural products.
3. Draw conclusions about the impact of specific populations on future agricultural trends.

<table>
<thead>
<tr>
<th>Introduction (Interest Approach)</th>
<th>Estimated Time: 5 minutes</th>
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</thead>
<tbody>
<tr>
<td>Have students get in their partner groups from the previous day and verbally compare research experiences from their data collection. This discussion should focus on reflection of experiences.</td>
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<table>
<thead>
<tr>
<th>Learning Activity 1</th>
<th>Estimated Time: 35 minutes</th>
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<tbody>
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<tr>
<td>Instructor Directions / Materials</td>
<td>Brief Content Outline</td>
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<tr>
<td>Students will use Microsoft Excel (if computers are available) or a sheet of paper to combine data collected by partners. After data is combined, students will create graph(s) that represent their data (this will be done in Excel or on graph paper based on the availability of computers) and create an “Introduction” paragraph that explains their research question and hypothesis and a “Results and Conclusions” paragraph that summarize their findings and accept or reject their hypothesis.</td>
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</table>

During this time, the teacher should monitor student progress and ask students questions about their tests and findings.

<table>
<thead>
<tr>
<th>Summary (Review)</th>
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<tbody>
<tr>
<td>Going around the room, each student should be asked to give one aspect of their study they found interesting. This should be a statement that would cause others to want to learn more about the study.</td>
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<table>
<thead>
<tr>
<th>Evaluation</th>
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<tbody>
<tr>
<td>Students will be evaluated through their field test results, paragraphs, and Agricultural Trends Results sheet during the next class.</td>
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</table>

<table>
<thead>
<tr>
<th>Items Students Turn In</th>
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<tbody>
<tr>
<td>None.</td>
</tr>
<tr>
<td>Daily Plan</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Lesson Title:</strong> Agricultural Demands of Consumer Populations – Presentation of Data</td>
</tr>
<tr>
<td><strong>Unit Title:</strong> Economic Impacts</td>
</tr>
<tr>
<td><strong>Course:</strong> Agriscience Foundations</td>
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<tr>
<td><strong>Estimated Time:</strong> 45 minutes</td>
</tr>
<tr>
<td><strong>Materials, Supplies, Equipment, References, and Other Resources:</strong></td>
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<tr>
<td>Student graphs and paragraphs from the previous class</td>
</tr>
<tr>
<td>Agricultural Trends Results sheet (classroom set)</td>
</tr>
<tr>
<td><strong>Agriscience Foundations Standards:</strong></td>
</tr>
<tr>
<td>1.02 – Analyze the impact of agriculture on the local, state, national, and global economy.</td>
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<tr>
<td>6.01 – Explain the economic importance of animals and the products obtained from animals.</td>
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<td>3.06 – Interpret, analyze, and report data.</td>
</tr>
<tr>
<td><strong>Essential Question:</strong></td>
</tr>
<tr>
<td>How does the agricultural industry contribute to our economy?</td>
</tr>
<tr>
<td><strong>Daily Objectives</strong></td>
</tr>
<tr>
<td>1. Draw conclusions based on data analysis.</td>
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<tr>
<td>2. Evaluate data and conclusions drawn regarding populations’ impact on agriculture products.</td>
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</table>

<table>
<thead>
<tr>
<th>Introduction (Interest Approach)</th>
<th>Estimated Time: 5 minutes</th>
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<tbody>
<tr>
<td>Students should be given approximately 5 minutes to finish up any work to their graphs and Introduction and Results/Conclusions paragraphs from the previous class. When all groups are finished, the graphs and the two paragraphs should be displayed around the room, either on the walls or on student desks.</td>
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### Learning Activity 1

<table>
<thead>
<tr>
<th>Estimated Time: 25 minutes</th>
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<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
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<tr>
<td>Each student group should briefly explain their project to the class, highlighting the following features:</td>
</tr>
<tr>
<td>- The population</td>
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<tr>
<td>- The food</td>
</tr>
<tr>
<td>- The setting</td>
</tr>
<tr>
<td>- The results and conclusions</td>
</tr>
<tr>
<td>Each group’s presentation should take approximately 1-2 minutes.</td>
</tr>
</tbody>
</table>
Agricultural Trends Results

Name ________________________

1. Did anyone do a study similar to yours with regard to population or food type? How do their results compare to yours?

2. Describe the results of one study you found particularly interesting. Explain the parts of the study you found interesting.

3. Explain one study where the results were as you expected. Why did you expect those results?

4. Explain one study where the results surprised you. What were the results, and why did you expect them to be different?

5. Based on what you learned yesterday about populations and trends and about food preferences of populations from the class’s field tests, make at least two predictions about populations’ impact on the food industry that were not mentioned by the USDA.
Introduction (Interest Approach)

Ask students to work independently to develop an outline following a hamburger patty from field to fork. Have selected students share their outlines, and ask students to consider how this chain might be different if cultured meat is produced.
Learning Activity 1

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Estimated Time: 25 minutes</th>
<th>Brief Content Outline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explain to the class what each segment of the food supply chain is responsible for. Arrange students into nine groups, assigning each group to an aspect of the food supply chain. Have the students develop a list of ways that their food chain segment might change and items they might be responsible for if cultured meat were to be mass produced.</td>
<td>1. Food supply chain – businesses that collectively produce consumable items. The chain involves all aspects of food production from pre-production research to post-consumption waste disposal</td>
<td></td>
</tr>
<tr>
<td>Guiding questions – How would cultured meat production change your segment’s responsibilities? Would your segment of the food chain be responsible for different things? What do you think they would need to do differently? Would your segment’s responsibilities impact the actions of other segments?</td>
<td>a. Pre-production – research and development</td>
<td></td>
</tr>
<tr>
<td>Have each group present their list. The class should consider how the presented ideas would fit with or impact their segment’s responsibilities.</td>
<td>b. Inputs – feed suppliers, veterinarians, breeders</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c. producer – cow/calf operations, feeder operation</td>
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</tr>
<tr>
<td></td>
<td>d. processor – slaughter, packing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>e. distributor – marketers, food distributors.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>f. wholesaler – sells to retailers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>g. retailer - supermarkets</td>
<td></td>
</tr>
<tr>
<td></td>
<td>h. consumer – people that buy the foods</td>
<td></td>
</tr>
<tr>
<td></td>
<td>i. post-consumption – waste disposal, recycling</td>
<td></td>
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</tbody>
</table>

Summary (Review)

Using the “6 Degrees of Ag. Production” sheet, students will link the production of lab grown meat with various economic repercussions through the potential relationship between supply and demand and changes to the food supply chain. This sheet will be used at the beginning of the next class.

Evaluation

Students will be evaluated through their presentations and Six Degrees of Ag. Production sheets next class.

Items Students Turn In

None.
Six Degrees of Ag. Production

Name __________________

Instructions: Consider the avenues between and contributors to the food supply chain. By focusing on these areas, explain how the production of cultured meat might lead to the following impacts on the economy. Try to make the most direct connection by including the least number of “degrees”, or steps.

Example:

Cultured meat production ————→ more expensive leather

less live cattle needed ————→ fewer cattle hides produced as by-products

less leather supplied ————→ more expensive leather

Cultured meat production ————→ increase in pet calves

Cultured meat production ————→ decrease in cost of stuffing during thanksgiving

Cultured meat production ————→ increase in number of unemployed veterinarians
<table>
<thead>
<tr>
<th>Daily Plan</th>
<th>Socio-Scientific Issues Instruction – Day 14</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lesson Title:</strong></td>
<td>The Impact of GMOs on the Economy</td>
</tr>
<tr>
<td><strong>Unit Title:</strong></td>
<td>Economic Impact</td>
</tr>
<tr>
<td><strong>Course:</strong></td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>45 minutes</td>
</tr>
</tbody>
</table>

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

Six Degrees of Ag. Production sheet – completed last class
Paper and pencil for each student

**Agriscience Foundations Standards:**

1.02 – Analyze the impact of agriculture on the local, state, national, and global economy.

6.01 – Explain the economic importance of animals and the products obtained from animals.

6.07 – Investigate the nature and properties of food, fiber, and by-products from animals.

**Essential Question:**

How might GMOs impact our economy?

**Daily Objectives**

1. Describe the links between the production of cultured meat and various economic outcomes.
2. Predict the economic outcomes of potential cultured meat introduction scenarios on various groups, including agricultural sectors and consumers.

<table>
<thead>
<tr>
<th>Introduction (Interest Approach)</th>
<th>Estimated Time: 10 minutes</th>
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</thead>
<tbody>
<tr>
<td>In groups of 3-4, have students compare their steps on the “Six Degrees of Ag. Production” sheet that they developed between the production of cultured meat and the various economic repercussions. During the discussion, they should be directed to ask one another about any possible missing steps or actions, or any leaps in logic between the steps that might not be realistic.</td>
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</tbody>
</table>
# Learning Activity 1

<table>
<thead>
<tr>
<th><strong>Instructor Directions / Materials</strong></th>
<th><strong>Estimated Time: 25 minutes</strong></th>
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</table>
| Individually, have students choose one of the cultured meat introduction scenarios from the unit content. If students would like to, they can develop their own scenario with the teacher’s approval. Students will individually write an essay explaining the potential positive and negative economic outcomes to consumers and various agricultural producers, including impacts on by-products, value-added products, and input products caused by the scenario chosen. The essay should include:  
1. Immediate economic impacts on consumers and agricultural producers  
2. Long term economic impacts on consumers and agricultural producers  
3. Economic impacts related to the production of input products necessary to raise traditional meat and/or grow cultured meat  
4. Economic impacts related to by-products and value-added products increased or decreased in supply by the production of cultured meat  
5. The student’s viewpoint related to whether the chosen scenario would be economically beneficial overall based on the above four aspects. | 1. Cultured meat introduction scenarios:  
a. Used as a non-human foodsource (pet food, animal feeds)  
b. Introduced to malnourished countries  
c. Introduced as a high-end product to affluent populations  
d. Introduced as an ingredient in ground and processed meat products  
e. Introduced as an animal-friendly option for vegetarians |

## Summary (Review)

<table>
<thead>
<tr>
<th><strong>Estimated Time: 10 minutes</strong></th>
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</thead>
</table>
| Students will trade essays and provide comments related to:  
1. Grammar, sentence structure, spelling, etc.  
2. Connection between the stated economic impacts and the student’s viewpoint on whether the scenario is beneficial economically (is the viewpoint supported by the stated impacts?)  
3. Logic of the stated economic impacts related to the scenario (are those impacts likely?)  
|  
The comments should be written directly on the essay. Essays should be turned in upon leaving class. |
<table>
<thead>
<tr>
<th><strong>Evaluation</strong></th>
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<tbody>
<tr>
<td>Students will be evaluated on their essays and essay comments.</td>
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</table>

<table>
<thead>
<tr>
<th><strong>Items Students will Turn In</strong></th>
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<tbody>
<tr>
<td>Scenario/Impact Essays</td>
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</tbody>
</table>
**Introduction (Interest Approach)**

Estimated Time: 5 minutes

Explain to students that they will be taking the Economic Impacts Posttest.
## Learning Activity 1

**Estimated Time: 15 minutes**

**Instructor Directions / Materials**

Students will complete the Economic Impacts Posttest. Standard testing procedures should be enforced. Tests should be turned in upon completion.

**Brief Content Outline**

Students will complete the Economic Impacts Posttest. Standard testing procedures should be enforced. Tests should be turned in upon completion.

---

## Learning Activity 2

**Estimated Time: 25 minutes**

**Instructor Directions / Materials**

Have students read the two economic impacts arguments – one promoting traditionally grown meat based on economic reasons and one advocating cultured meat based on economic reasons. These do not have to be read very carefully – reading both articles should take approximately 15 minutes

Split the room in half (just the room – not the students) with an “I agree” side and an “I disagree” side. Explain to students that you will be making statements based on cultured meat based on its impacts on the economy. Statements are provided on the attached sheet. After each statement, the students should move to the side of the room that describes their opinion.

After the students move to their respective opinion sides of the room for the first statement, ask them questions about their reasons for moving to that side. Do this for each of the questions on the sheet.

*Guiding questions – Why do you agree/disagree with this statement? Why do you think other people disagree with that opinion? (ask appropriate questions if any students walk toward the middle of the room indicating their indecision as well)*

---

## Summary (Review)

**Estimated Time: 0 minutes**

The discussion in Learning Activity 2 serves as a summary for this class.
<table>
<thead>
<tr>
<th>Evaluation</th>
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<tr>
<td>Students will be evaluated on their Economic Impacts Posttests.</td>
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</table>

<table>
<thead>
<tr>
<th>Items Students Turn In</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic Impacts Posttest</td>
</tr>
</tbody>
</table>
Statements Sheet

1. Cultured meat will improve the nation’s overall economy.

2. Traditionally grown meat is a cost-effective food source.

3. Cultured meat has economic benefits that traditionally grown meat does not.

4. Traditionally grown meat supports more employees than cultured meat production would.

5. Cultured meat production is more beneficial for consumers than producers.

6. I think cultured meat should be produced to allow the nation to experience some of its economic benefits.

7. I think traditionally grown meat has ways they can improve their economic impacts on consumers and producers.
Eight Ways In-Vitro Meat will Change Our Lives
By: Hank Hyena
Published: November 17, 2009

"Future Flesh" is squatting on your plate. Are you nervous? Stab it with a fork. Sniff it. Bite! Chew, swallow. Congratulations! Relax and ruminate now because you’re digesting a muscular invention that will massively impact the planet.

In-Vitro Meat — aka tank steak, sci fi sausage, petri pork, beaker bacon, Frankenburger, vat-grown veal, laboratory lamb, synthetic shmeat, trans-ham, factory filet, test tube tuna, cultured chicken, or any other moniker that can seduce the shopper’s stomach — will appear in 3-10 years as a cheaper, healthier, "greener" protein that’s easily manufactured in a metropolis. Its entree will be enormous; not just food-huge like curry rippling through London in the 1970’s or colonized tomatoes teaming up with pasta in early 1800’s Italy. No. Bigger. In-Vitro Meat will be socially transformative, like automobiles, cinema, vaccines.

H+ previously discussed In-Vitro Meat, as have numerous other publications [see references at the end of this article]. Science pundits examined its microbiological struggles in Dutch labs and at New Harvest, a Baltimore non-profit. Squeamish reporters wasted ink on its "yucky" and "unnatural" creation, while others wondered if its "vegan" or not (PETA supports it but many members complain). This article jumps past artificial tissue issues; anticipating success, I optimistically envision Eight Ways In-Vitro Meat Will Change Our Lives.

When In-Vitro Meat (IVM) is cheaper than meat-on-the-hoof-or-claw, no one will buy the undercut opponent. Slow-grown red meat & poultry will vanish from the marketplace, similar to whale oil’s flame out when kerosene outshone it in the 1870’s. Predictors believe that IVM will sell for half the cost of its murdered rivals. This will grind the $2 trillion global live-meat industry to a halt (500 billion pounds of meat are gobbled annually; this is expected to double by 2050). Bloody sentimentality will keep the slaughterhouses briefly busy as ranchers quick-kill their inventory before it becomes worthless, but soon Wall Street will be awash in unwanted pork bellies.
Special Note: IVM sales will be aided by continued outbreaks of filthy over-crowded farm animal diseases like swine flu, Mad Cow, avian flu, tuberculosis, brucellosis, and other animal-to-human plagues. Public hysteria will demand pre-emptive annihilation of the enormous herds and flocks where deadly pathogens form, after safe IVM protein is available.

2. Urban Cowboys.
Today’s gentle drift into urbanization will suddenly accelerate as unemployed livestock workers relocate and retrain for city occupations. Rural real estate values will plummet as vast tracts of ranch land are abandoned and sold for a pittance (70% of arable land in the world is currently used for livestock, 26% of the total land surface, according to the United Nations Food and Agriculture Organization). New use for ex-ranch land? Inexpensive vacation homes; reforested parks; fields of green products like hemp or bamboo. Hot new city job? Techies and designers for In-Vitro Meat factories.

3. Healthier Humans.
In-Vitro Meat will be 100% muscle. It will eliminate the artery-clogging saturated fat that kills us. Instead, heart-healthy Omega-3 (salmon oil) will be added. IVM will also contain no hormones, salmonella, e. coli, campylobacter, mercury, dioxin, or antibiotics that infect primitive meat. I’ve noted above that IVM will reduce influenza, brucellosis, TB, and Mad Cow Disease. Starvation and kwashiokor (protein deficiency) will be conquered when compact IVM kits are delivered to famine-plagued nations. The globe’s water crises will be partially alleviated, due to our inheritance of the 8% of the H2O supply that was previously gulped down by livestock and their food crops. We won’t even choke to death because IVM contains no malicious bones or gristle. (Although Hall of Fame slugger Jimmy Foxx choked to death on a chicken bone, about 90% of meat victims are murdered by steak).
Today’s meat industry is a brutal fart in the face of Gaia. A recent Worldwatch Institute report ("Livestock and Climate Change") accuses the world’s 1.5 billion livestock of responsibility for 51% of all human-caused greenhouse gas emissions. Statistics are truly shitty: cattle crap 130 times more volume than a human, creating 64 million tons of sewage in the United States that’s often flushed down the Mississippi River to kill fish and coral in the Gulf of Mexico. Pigs are equally putrid. There’s a hog farm in Utah that oozes a bigger turd total than the entire city of Los Angeles. Livestock burps and farts are equally odious and ozone-destroying. 68% of the ammonia in the world is caused by livestock (creating acid rain), 65% of the nitrous oxide, 37% of the methane, 9% of the CO2, plus 100 other polluting gases. Big meat animals waste valuable land — 80% of Amazon deforestation is for beef ranching, clear-cutting a Belgium-sized patch every year. Water is prodigiously gulped — 15,000 liters of H20 produces just one kilogram of beef. 40% of the world’s cereals are devoured by livestock. This scenario is clearly unsustainable, and In-Vitro Meat is the sensible alternative. (Although skeptics warn that IVM factories will produce their own emissions, research indicates that pollution will be reduced by at least 80%.) Once we get over the fact that IVM is oddly disembodied, we’ll be thankful that it doesn’t shit, burp, fart, eat, over graze, drink, bleed, or scream in pain.

5. Economic Upheaval.
The switch to In-Vitro Meat will pummel the finances of nations that survive on live animal industries. Many of the world leaders in massacred meat (USA, China, Brazil) have diversified incomes, but Argentina will bellow when its delicious beef is defeated. New Zealand will bleat when its lamb sales are shorn. And ocean-harvesting Vietnam and Iceland will have to fish for new vocations. Industries peripherally dependent on meat sales, like leather, dairy and wool, will also be slaughtered. Hide and leather-exporting nations like Pakistan and Kenya will be whipped, but South Korea will profit on its sales of "Koskin" and other synthetic leathers. Huge plantations of livestock crops (soybeans & corn) in Brazil, USA, Argentina, and China can be replaced with wool substitutes like sisal. Smaller nations that excel in food processing will thrive because they’ll export IVM instead of importing tonnage of frozen meat. Look for economic upticks in The Netherlands, Belgium, Denmark, France, and especially Japan, who’s currently one of the globe’s largest importers of beef.

6: Exotic & Kinky Cuisine.
In-Vitro Meat will be fashioned from any creature, not just domestics that were affordable to farm. Yes, ANY ANIMAL, even rare beasts like snow leopard, or Komodo Dragon. We will want to taste them all. Some researchers believe we will also be able to create IVM using the DNA of extinct beasts — obviously, "DinoBurgers" will be served at every six-year-old boy’s birthday party.
Humans are animals, so every hipster will try Cannibalism. Perhaps we’ll just eat people we don’t like, as author Iain M. Banks predicted in his short story, "The State of the Art" with diners feasting on "Stewed Idi Amin." But I imagine passionate lovers literally eating each other, growing sausages from their co-mingled tissues overnight in tabletop appliances similar to bread-making machines. And of course, masturbatory gourmands will simply gobble their own meat.

7: FarmScrapers.
The convenience of buying In-Vitro Meat fresh from the neighborhood factory will inspire urbanites to demand local vegetables and fruits. This will be accomplished with "vertical farming" — building gigantic urban multi-level greenhouses that utilize hydroponics and interior grow-lights to create bug-free, dirt-free, quick-growing super veggies and fruit (from dwarf trees), delicious side dishes with IVM. No longer will old food arrive via long polluting transports from the hinterlands. Every metro dweller will purchase fresh meat and crispy plants within walking distance. The success of FarmScrapers will cripple rural agriculture and enhance urbanization.

8. We Stop the Shame.
In-Vitro Meat will squelch the subliminal guilt that sensitive people feel when they sit down for a carnivorous meal. Forty billion animals are killed per year in the United States alone; one million chickens per hour. I list this last even though it’s the top priority for vegetarians, because they represent only 1-2% of the population, but still… IVM is a huge step forward in "Abolitionism" — the elimination of suffering in all sentient creatures. Peter Singer, founding father of Animal Liberation, supports IVM. So does every European veggie group I contacted: VEBU (Vegetarian Federation of Germany), EVA (Ethical Vegetarian Alternative of Belgium), and the Dutch Vegetarian Society. And PETA, mentioned earlier, offers $1 million to anyone who can market a competitive IVM product by 2012.

My final prediction is this: In-Vitro Meat relishes success first in Europe, partly because its "greener," but mostly they already eat "yucky" delicacies like snails, smoked eel, blood pudding, pig’s head cheese, and haggis (sheep’s stomach stuffed with oatmeal). In the USA, IVM will initially invade the market in Spam cans and Hot Dogs, shapes that salivating shoppers are sold on as mysterious & artificial, but edible & absolutely American.
Beef Market At A Glance

Statistics About America’s No. 1 Selling Protein

The Men and Women of American Agriculture

Beef cattle production represents the largest single segment of American agriculture. In 2007, more farms were classified as beef cattle operations (31 percent) than any other type of farm.1

- The U.S. beef industry is made up of more than 1 million businesses, farms and ranches.2
- In 2007, there were more than 1 million cattle ranchers and farmers in the United States.1
- The American Veal Association estimates there are 800-900 veal producers in the United States.3
- In 2007, more than 97 percent of beef cattle farms and ranches in the United States were family farms.4

The U.S. Cattle Supply

In 2008, the production of meat animals was responsible for more than $66 billion in added value to the U.S. economy, as measured by contribution to the national output.4

- On Jan. 1, 2009, there were 94.5 million cattle in the United States.2
- In 2008, 34.4 million cattle were harvested. That means more than 660,000 cattle are harvested in the United States every week.2
- In 2008, 26.6 billion pounds of beef were produced.2
- U.S. cash receipts from cattle and calves in 2007 were estimated at $50.7 billion.2
- Total U.S. beef exports were valued at nearly $3.62 billion in 2008.3

Strong Demand for Beef

Consumers’ love of great steaks and burgers, their confidence in the safety of U.S. beef and their renewed interest in the nutritional benefits of protein help create strong demand for beef.

- Consumer spending on beef was $76 billion in 2008 and has grown $26.9 billion since 1999.2
- Per capita spending for beef in retail and foodservice was about $249 in 2008 — up about $50 from 2001.2
- In 2008, per capita consumption of beef was 59.9 pounds, compared to 59.2 pounds for chicken.2
Today’s Consumer
The demographic make-up of the domestic consumer continues to evolve. The following trends have been identified: a growing and aging population; the emerging strength of the millennial generation, who are entering their prime household formation years; an increase in small households of one to two members and an increase in ethnic diversity.5

Beef in Retail
Beef dominates the retail meat department in volume (pounds) of sales and total dollar amount. Additionally, the value of beef sales continues to increase.6

The following statistics represent supermarkets with annual sales of $2 million or more. Data does not include club stores, butcher shops or independent grocery stores with annual sales of less than $2 million.

- Total fresh beef sales at retail were $15.5 billion in 2008, a 2.2-percent sales growth from the previous year.4
- Beef accounts for more than 52 percent of dollars spent on meat at retail. In comparison, chicken accounts for 22 percent of dollars spent on meat at retail.6
- In 2008, 4.2 billion pounds of fresh beef were sold at retail, a 2 percent volume growth from the previous year.6
- In 2008, beef accounted for 39.3 percent of the pounds of meat purchased at retail.6
- The average price per pound of beef in 2008 was $3.69.6
- The volume and value of natural/organic beef product purchases have declined in recent months. For the year ending March 29, 2009, natural/organic beef sales comprised 1.8 percent of the total beef volume (pounds) and 2.7 percent of the total beef sales (dollars) in retail. This represents a 5.6 percent reduction in total pounds and a 5 percent reduction in total dollars from the previous year.6

Beef in Foodservice
The foodservice sector includes both “restaurants” (limited and full service) and “beyond restaurants,” such as lodging, business and industry (e.g., private, corporate and employee dining facilities), colleges and schools.

Of the total dollar amount spent on food and beverages in 2008, approximately 50 percent went to retail outlets and 50 percent to foodservice establishments. In 2008, Americans spent $540 billion in the foodservice sector.7 Importantly, beef remains the No. 1 protein served in restaurants.7

- Overall, the foodservice sector purchased 8.18 billion pounds of beef in 2008. This equated to $26.3 billion in wholesale purchases. Foodservice purchased 7.81 billion pounds of chicken in 2008.7
- Ground beef represents the largest share of volume in foodservice at 63 percent while the steak category represents the largest share of dollars at 42 percent.7
Beef in Foodservice (continued)

The following statistics measure beef volume in commercial restaurants, which account for about 66 percent of all consumer spending in foodservice.

- In 2008, 5.4 billion pounds of beef were purchased by commercial restaurant operators.7
- Commercial restaurants include limited service restaurants (LSRs), such as McDonald's, Pizza Hut, Subway and Church's, and full service restaurants (FSR). FSRs are divided into midscale restaurants such as Denny's, Golden Corral and Cracker Barrel; casual dining restaurants such as Olive Garden, Applebee's and Red Lobster; and fine dining restaurants such as Morton's and Del Frisco's.
- LSRs accounted for more than 43 percent of all beef and 41 percent of all chicken served in commercial restaurants in 2008.7
- In 2008, beef accounted for 39.3 percent of the pounds of meat purchased at retail.6
- The average price per pound of beef in 2008 was $3.69.6
- The volume and value of natural/organic beef product purchases have declined in recent months. For the year ending March 29, 2009, natural/organic beef sales comprised 1.8 percent of the total beef volume (pounds) and 2.7 percent of the total beef sales (dollars) in retail. This represents a 5.6 percent reduction in total pounds and a 5 percent reduction in total dollars from the previous year.6

Beef in the Home

More than eight out of 10 individuals consume fresh beef regularly (an average of 1.7 times per week) in-home.9

- Ground beef is the most popular beef item for consumers preparing meals in their home. In 2008, ground beef was present at 60 percent of all in-home beef servings. Steak is the second most popular in-home beef item.9
- Although families represent less than one-third of households, they represent more than half of fresh beef servings.9

Unless otherwise noted, all statistics are for year 2008.
1 USDA National Agricultural Statistical Service
2 Carlisle, April 2008
3 American Vet Association
4 USDA Economic Research Service
5 U.S. Meat Export Federation
6 Puslook Data /IHS Scannen Data Research
7 Technicon, Inc.
8 U.S. Department of Commerce, Bureau of the Census
9 U.S. NDA through National Data Services
### Daily Plan

<table>
<thead>
<tr>
<th><strong>Lesson Title:</strong></th>
<th>Evaluating Arguments for and against Cultured Meat</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit Title:</strong></td>
<td>Introduction to Cultured Meat</td>
</tr>
<tr>
<td><strong>Course:</strong></td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>45 minutes</td>
</tr>
</tbody>
</table>

#### Materials, Supplies, Equipment, References, and Other Resources:
- Classroom set of computers with internet connections
- Cultured Meat – You Decide Reflection Guide (classroom set)

#### Agriscience Foundations Standards:
- 3.06 – Interpret, analyze, and report data
- 3.08 – Evaluate advances in biotechnology that impact agriculture (e.g. transgenic crops, biological controls, etc.)
- 9.03 – Identify and demonstrate ways to be an active citizen.
- 9.05 – Demonstrate the ability to work cooperatively.

#### Essential Question:
How would the incorporation of cultured meat into the nation’s food supply impact consumers, the agricultural industry, the environment, and the economy?

#### Daily Objectives
1. Evaluate evidence advocating and opposing the introduction of cultured meat into the nation’s food supply.
2. Develop a supported position related to the introduction of cultured meat into the nation’s food supply.

### Introduction (Interest Approach)

**Estimated Time: 5 minutes**

Ask the class to hold up a “thumbs up” or “thumbs down” indicating whether they think cultured meat should be produced as a food supply. Ask several students to give one reason supporting their decision. This should be done at a rapid pace rather than as an in-depth discussion.

Ask the class if their opinions have changed at all since the beginning of class. Explain that as scientists obtain new data, their opinions can change to help them make better informed decisions.
<table>
<thead>
<tr>
<th>Learning Activity 1</th>
<th>Estimated Time: 35 minutes</th>
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<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>Each student should get a computer. Explain to students that they will be learning about different points supporting or opposing cultured meat. Individually, they will be answering questions on the reflection guide and clicking on their opinions on the website to develop an educated argument for or against cultured meat. Tell students to go to the Harvest of Fear website, <a href="http://www.pbs.org/wgbh/harvest/exist/">http://www.pbs.org/wgbh/harvest/exist/</a>. Go over the website’s directions with the students – they should fully understand that they can alter their decisions for each argument (cultured meat may seem like a good idea to alleviate one problem, but may seem like a bad idea related to another problem), and that the next argument posted is dependent on their answer, so they should respond to each argument thoughtfully. While they go through the website, students should also write responses down on the reflection guide. This should be turned in when class is over.</td>
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<table>
<thead>
<tr>
<th>Summary (Review)</th>
<th>Estimated Time: 5 minutes</th>
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<tbody>
<tr>
<td>If there is time at the end of class, hold a brief class discussion about how their responses changed or stayed the same based on the arguments they saw, as well as whether they had a difficult time choosing their opinions and if their overall viewpoint was altered by the website’s arguments. This discussion is an extension of the reflection guide that students completed during the activity, so it is not necessary to discuss if time does not allow.</td>
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<th>Evaluation</th>
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<tr>
<td>Students will be evaluated on their reflection guides.</td>
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<table>
<thead>
<tr>
<th>Items Students Turn In</th>
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</thead>
<tbody>
<tr>
<td>Reflection Guide</td>
</tr>
</tbody>
</table>
Cultured Meat – You Decide Reflection Guide

Name ______________________________

Quote from introduction that surprised me:

Quote from introduction that I already knew:

Based on what you know now, do you think we should grow GM crops?

- Yes
- No

Quote from introduction that led me to answer this way:

Quote from health factors that surprised me:

Quote from health factors that I already knew:

Based on what you know now, do you think we should grow GM crops?

- Yes
- No

Quote from health factors that led me to answer this way:
Quote from regulation that surprised me:

Quote from regulation that I already knew:

Based on what you know now, do you think we should grow GM crops?

Yes  No

Quote from regulation that led me to answer this way:

Idea or thought from the arguments that held the greatest weight for me:

Idea or thought from the arguments that meant very little to me:

Based on what you know now, do you think we should grow GM crops?

Yes  No

What you would say to convince someone to agree with your viewpoint:
### Daily Plan

<table>
<thead>
<tr>
<th><strong>Lesson Title:</strong></th>
<th>Agriculture’s Use of Environmental Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit Title:</strong></td>
<td>Environmental Impact</td>
</tr>
<tr>
<td><strong>Course:</strong></td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>45 minutes</td>
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</tbody>
</table>

**Materials, Supplies, Equipment, References, and Other Resources:**
- Environmental Impacts Pretest
- Computer hooked to a projector and internet access
- Livestock Production & the Environment video ([http://www.youtube.com/watch?v=cvCoWh77w1s](http://www.youtube.com/watch?v=cvCoWh77w1s)) Note – also available on dropbox.
- Environmental Resources in Agriculture powerpoint
- Environmental Resources Guide (classroom set)

**Agriscience Foundations Standards:**
- 1.04 – Examine the role of the agricultural industry in the interaction of population, food, energy, and the environment.
- 4.03 – Describe the environmental resources (soil, water, air) necessary for agriculture production.

**Essential Question:**
How does the agricultural industry use environmental resources?

**Daily Objectives**
1. Identify agricultural practices that rely on environmental resources.
2. Describe the characteristics of agricultural practices that utilize environmental resources.

### Introduction (Interest Approach)

**Estimated Time: 10 minutes**

Have students watch the video clip ([http://www.youtube.com/watch?v=cvCoWh77w1s](http://www.youtube.com/watch?v=cvCoWh77w1s)), focusing on the meat production industry’s environmental impacts. Before the video begins, ask students to consider their own viewpoints during the video regarding the following:
1. What they already know about the relationship between agriculture and the environment.
2. Whether they agree with the viewpoints offered in the video, and why or why not.

Hold a brief discussion after the video, asking students about their thoughts on the above two aspects.

<table>
<thead>
<tr>
<th>Learning Activity 1</th>
<th>Estimated Time: 15 minutes</th>
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</thead>
<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>Students will complete the Environmental Impacts Pretest. All tests should be turned in upon completion.</td>
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</table>

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<thead>
<tr>
<th>Learning Activity 2</th>
<th>Estimated Time: 20 minutes</th>
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<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
</tbody>
</table>
| Using the powerpoint, lecture to students on the utilization of environmental resources in the agricultural industry. During the lecture, students should take notes and offer their considerations on the Environmental Resources Guide. *Note – Teachers should review the guide prior to viewing the powerpoint – the questions on the guide are answered in the powerpoint, but students should try to answer them before learning the answers in lecture.* The guide asks students to consider how each of the resources and the characteristics of their current uses would be impacted by future population growth and by the introduction of cultured meat. | 1. Agricultural industry accounts for 80% of nation’s water usage  
   a. Primarily for irrigation  
   b. Irrigated cropland has increased by over 40%, but water application rates have decreased by 20%. Total quantity of irrigation water applied increased 10% since 1969.  
2. Land is agriculture’s most limited resource  
   a. Farm size  
   b. Three major uses are (in order) – grassland pasture and range (30.8% of nation’s land), forest-use land (29.5%) and cropland (23.3%). Urban use is 3.1% of nation’s land.  
   c. Grassland pasture and range  
   d. Forest-use land  
   e. Cropland  
   f. Urban areas |

Guiding questions – *How do you think population growth will impact the use of this resource? Do you think there is a way to maintain production rates and reduce use of this resource? Do you think high use of this resource is justified based on what is being produced? How might cultured meat impact use of this resource?*
<table>
<thead>
<tr>
<th>Summary (Review)</th>
<th>Estimated Time: 10 minutes</th>
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<tbody>
<tr>
<td>Using a think-pair-share format, have students share their considerations from their guides with partners and then with the class.</td>
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<tr>
<th>Evaluation</th>
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<tbody>
<tr>
<td>Students will be evaluated using their pretests.</td>
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<tr>
<th>Items Students Turn In</th>
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</thead>
<tbody>
<tr>
<td>Environmental Impact Pretests</td>
</tr>
</tbody>
</table>
Name ______________________________  Environmental Resources Guide

Water

What do you think all this water is used for?

In the circle below, shade in the percentage increase in water applied.

In the circle below, shade in the percentage increase in irrigated cropland.

Why didn’t the increase of irrigated cropland equal the increase of water irrigation?

List some examples of agricultural practices or innovations that you think have caused a decrease in water application rates.

Land

Why is land agriculture’s most limited resource?

In the circle below, shade in the percentage of farms that are considered “small family farms”.

Based on this, what amount of total production do you think comes from small family farms?

In the circle below, shade in the percentage of total production that comes from small family farms.

How does this compare to your prediction? Why do you think the total percentage of production from small family farms is different from the total percentage of farms that are considered small family farms?
How much farmland was owned by the most productive 2% of US farms?

In the circle below, shade in the percentage of farm sales that came from 2% of US farms.

What size farms would you expect to make up this 2%?

In the circle below, shade in (using three different colors or patterns) the percentages of land use in the US.

Grassland

Predict the reasons for decreased grassland pasture.

Were your predictions accurate? If not, what are the reasons?

Forest-Use Land

How does the agricultural industry utilize forest-use land?

Cropland

What are some causes of decreased available cropland in recent decades?

How is the nation able to maintain high levels of production on reduced cropland?

In the circle below, use three different colors or patterns to shade in the percentages of cropland used to produce certain types of crops.

Urbanized Land

Why do you think urbanized land increased at a greater rate than the US population?

Do you think the impact or urban growth on agricultural resources is enough of a reason to slow urban growth? Support your response.
Environmental Resources used in Agricultural Practices

**Land**
- Agriculture's most limited resource
- Farm size:
  - Small family farms (sales less than $10,000) make up more than half of all farms,
  - Small family farms account for 27% of production
  - In 2002, half of all farm sales came from 2% of US farms and 11% of farm land (increasing number of large farms)

**Water**
- Agriculture accounts for 80% of nation's water usage
  - Used primarily for irrigation
  - Since 1969:
    - Total quantity of irrigation water applied increased 50%
    - Irrigated cropland has increased by over 40%
  - Water application rates have decreased by 20%

**Forest-use Land**
- Includes forestry industry and parks, wilderness areas, wildlife areas, etc.

**Grassland Pasture**
- Less pasture and range is needed than in the past to sustain grazing herds
  - Improved forage quality
  - Productivity of land
  - Number of domestic animals (mainly sheep) has declined

**Land**
- Three major uses:
  - Grassland pasture and range (30.8% of nation's land)
  - Forest-use land (29.5%)
  - Cropland (23.3%)
Cropland has decreased in recent decades, but the nation can still produce high capacity of food and fiber.

- Improved forage quality
- Productivity of land
- Number of domestic animals (mainly sheep) has declined

Cropland changed into urban use is generally irreversible.

- Excessive loss of cropland to urban uses could lessen the production of food and fiber and the supply of rural amenities (open space, watershed protection, rural lifestyles).

Includes cropland used for crops, pasture, and idled.

- Corn for grain, soybeans, wheat, and hay accounted for 80% of all cropland harvested in 2002.
- Other principal crops accounted for 15%.
- Vegetables, fruit, nuts, melons, etc. accounted for 4.5%.

Remains low compared to agricultural uses.

<table>
<thead>
<tr>
<th>Daily Plan</th>
<th>Socio-Scientific Issues Instruction – Day 18</th>
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<tbody>
<tr>
<td><strong>Lesson Title:</strong></td>
<td>Environmental Perspectives and BMPs from an Extension Agent</td>
</tr>
<tr>
<td><strong>Unit Title:</strong></td>
<td>Environmental Impact</td>
</tr>
<tr>
<td><strong>Course:</strong></td>
<td>Agriscience Foundations</td>
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<tr>
<td><strong>Estimated Time:</strong></td>
<td>45 minutes</td>
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</table>

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

Guest speaker – Local extension agent. *This should be arranged ahead of time by the teacher through contact with an appropriate local extension agent. See interest approach and first learning activity for purpose of guest speaker.*

**Agriscience Foundations Standards:**

1.04 – Examine the role of the agricultural industry in the interaction of population, food, energy, and the environment.

4.03 – Describe the environmental resources (soil, water, air) necessary for agriculture production.

4.05 – Apply Best Management Practices that enhance the natural environment.

**Essential Question:**

How does the agricultural industry use environmental resources?

**Daily Objectives**

1. Explain the purposes of Best Management Practices related to environmental resources.
2. Determine the local status of conservation concerns and BMP implementation.

**Introduction (Interest Approach)** | Estimated Time: 20 minutes

Tell students that they will be writing a publication in partners designed for agricultural producers that recommends BMPs (this will require a brief explanation) they can use to improve water, land, and air quality. They will be writing the publications in the following class. To prepare for writing, they will be interviewing a local extension agent about local environmental concerns, how agricultural producers contribute to these concerns, BMPs that agricultural producers can do to alleviate environmental concerns, and the current status of local agricultural producers’ use of conservation BMPs.
During this 15 minutes, students should get into partners and write a list of questions they have regarding each of the following aspects of their publication writing:

- What are local environmental concerns
- How do agricultural producers contribute to these concerns
- What are some BMPs that the agent feels are most important in alleviating environmental concerns
- What is the current status of producers implementing these and other conservation BMPs

The list should include at least 2 questions per category, leading to a total of 8 questions.

During this time, the teacher should walk around the room, monitoring the questions developed by students and asking them questions that will increase the depth of the questions. The teacher should remind the student that the questions should be designed to give them answers that will help them in writing their publication. They should also be reminded that the publication will recommend specific BMPs that agricultural producers can use to improve water, land, and air quality.

<table>
<thead>
<tr>
<th>Learning Activity 1</th>
<th>Estimated Time: 20 minutes</th>
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<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>The local extension agent will speak with students about local conservation and BMPs, focusing on the questions asked by students. Students should write notes from the speaker’s discussion, focusing on items they may want to include in their publication and answers to questions from the class.</td>
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</table>

*The extension agent visit should be arranged ahead of time. The agent should be prepared to discuss how local agricultural producers are linked to environmental concerns and BMPs that help them improve environmental conservation. The agent should also be aware that discussion time is approximately 20 minutes.*
<table>
<thead>
<tr>
<th>Summary (Review)</th>
<th>Estimated Time: 5 minutes</th>
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<tbody>
<tr>
<td>If there is time after the discussion with the extension agent, have students briefly talk in their partners about items they learned from the speaker that they might want to include in their publication and a possible outline for writing their publication.</td>
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</table>

*This is an extension of the first learning activity in the following class. If time does not allow for this summary, it is not a serious problem.*

<table>
<thead>
<tr>
<th>Evaluation</th>
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<tbody>
<tr>
<td>Students will be evaluated through teacher monitoring during question development and during the following class through the publications.</td>
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</table>

<table>
<thead>
<tr>
<th>Items Students Turn In</th>
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<tbody>
<tr>
<td>None.</td>
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<tr>
<td>Daily Plan</td>
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<tr>
<td>------------</td>
</tr>
<tr>
<td><strong>Lesson Title:</strong></td>
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<tr>
<td><strong>Unit Title:</strong></td>
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<tr>
<td><strong>Course:</strong></td>
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<tr>
<td><strong>Estimated Time:</strong></td>
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</tbody>
</table>

**Materials, Supplies, Equipment, References, and Other Resources:**
- EDIS Publication, “The Ecology and Economics of Florida’s Ranches” (classroom set)
- BMPs handout (classroom set)

**Agriscience Foundations Standards:**
1.04 – Examine the role of the agricultural industry in the interaction of population, food, energy, and the environment.

4.03 – Describe the environmental resources (soil, water, air) necessary for agriculture production.

4.05 – Apply Best Management Practices that enhance the natural environment.

**Essential Question:**
How does the agricultural industry use environmental resources?

**Daily Objectives**
1. Explain the purposes of Best Management Practices related to environmental resources.
2. Evaluate how specific BMPs impact environmental quality.

**Introduction (Interest Approach)**
Estimated Time: 10 minutes

Have students read the EDIS Publication, The Ecology and Economics of Florida’s Ranches. Explain that EDIS publications are developed by the Extension System at UF to educate agricultural producers and consumers about best agricultural practices. As they read, have students use two highlight colors to signify items they find that indicate the care ranchers have for the environment and items they find that might cause public concern related to the environment.
### Learning Activity 1

**Estimated Time: 15 minutes**

**Instructor Directions / Materials**

Using their notes from the previous day’s discussion with the extension agent, the article from the interest approach, and the BMPs handout, have student partners design an outline of their publication. The publications should include:

- An introduction that explains why agricultural producers should engage in BMPs
- What BMPs are
- Specific BMPs recommended by the students
- Results of the BMPs (why are they good?)
- The concerns that are alleviated by each of the BMPs

During this time, the teacher should monitor student progress by asking groups questions about the BMPs they want to focus on, how they are deciding what information to include and exclude, and whether they have any questions.

**Brief Content Outline**

- Land Quality BMPs
- Water Conservation BMPs
- Air Quality BMPs

### Learning Activity 2

**Estimated Time: 20 minutes**

**Instructor Directions / Materials**

Have student partners split up their outline sections for writing purposes. Each student should be responsible for writing approximately half of their publication. Students should then individually write their sections of the publication.

Upon completion, student partners can trade written pieces for editing. Then the students should put their publication together to develop the finished publication.
### Summary (Review)

**Estimated Time: 5 minutes**

Students should turn in their written publications.

### Evaluation

Students will be evaluated through their written publications.

### Items Students Turn In

EDIS Publications
Best Management Practices

Land Quality BMPs – (National Resources Conservation Service)

1. **Enhance organic matter** – most important way to improve and maintain soil quality. Improves soil structure, protects soil from erosion and compaction, supports healthy habitat for soil organisms.
   a. Leave crop residues in the field
   b. Choose crop rotations that include high residue plants
   c. Use good nutrient and water management practices to grow plants with large roots and residue
   d. Grow cover crops
   e. Apply manure or compost
   f. Use low or no tillage systems
   g. Mulching

2. **Avoid excessive tillage** – minimizes loss or organic matter, protects soil surface with plant residue. Keeps good soil structure, reduces erosion, maintains healthy organism habitat, reduce soil compaction.

3. **Manage pests and nutrients efficiently** – reduces air and water pollution, reduces harm on beneficial soil organisms
   a. Test and monitor soil and pests
   b. Apply only necessary chemicals at the right time and place
   c. Use nonchemical approaches when possible

4. **Prevent soil compaction** – maintains air, water, and space available to plants within the soil.
   a. Reduce repeated or heavy traffic, heavy equipment, traveling on wet soil

5. **Keep the ground covered** – prevents drying, crusting, erosion, provides habitats for soil organisms, improves water availability
   a. Keep crop residue on surface
   b. Plant cover crops

6. **Diversity cropping systems** – each plant contributes a unique root structure and type of residue to the soil. Helps control pest populations, reduces weed and disease pressures (certain plants are more susceptible to certain pests), increases microorganism and organism diversity in soil.
   a. Use buffer strips (diversity at one time)
   b. Small diverse fields (diversity at one time)
   c. Crop rotation (diversity over time)

(over)
Water Conservation BMPs –

1. Developed by the USDA Natural Resources Conservation Service and EPS’s National Management Measures to Control Nonpoint Source Pollution

2. Purpose – reduce non-point sources of pollution from croplands through integrated use of best management practices

3. CORE 4 practices –
   a. Conservation tillage – leaving crop residue (plant materials from past harvests) on soil surface to reduce runoff and soil erosion, conserves soil moisture, keeps nutrients and pesticides in the field
   b. Crop nutrient management – accounting for all nutrient inputs helps ensure nutrients are available for crop needs and reduces nutrient movement off fields. Prevents buildup in soils.
   c. Pest management – various methods for keeping insects, weeds, disease, and other pests in check while protecting soil, water, and air quality
   d. Conservation buffers – provide barriers of protection by capturing pollutants that might otherwise move into surface water

4. Supplemental BMPs – aimed at benefitting production while protecting the environment
   a. Irrigation water management – reduces nonpoint source pollution of ground and surface waters from irrigation
   b. Grazing management – minimizes water quality impacts of grazing on pasture and range lands
   c. Animal feeding operations management – minimizes impacts of animal feeding operations and waste through runoff controls, waste storage, waste utilization, and nutrient management
   d. Erosion and sediment control – conserve soil and reduce sediment reaching water

Air Quality BMPs –

1. Improve ruminant animals’ production efficiency – certain substances, such as urea increases animal’s ability to digest food, so less methane is produced
   a. Supplement animals’ diet

2. Participate in methane recovery efforts – uses methane from livestock facilities to create energy
   a. AgSTAR Program- sponsored by EPA, USDA, US Dept. of Energy

3. Participate in National Clean Diesel Campaign

4. Clean Agriculture USA Program helps farmers, ranchers, and agribusinesses reduce emissions from older engines that are in operation
### Daily Plan

<table>
<thead>
<tr>
<th>Lesson Title:</th>
<th>Environmental Impacts – Informing Agricultural Producers</th>
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<tbody>
<tr>
<td>Unit Title:</td>
<td>Environmental Impacts</td>
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<tr>
<td>Course:</td>
<td>Agriscience Foundations</td>
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<tr>
<td>Estimated Time:</td>
<td>45 minutes</td>
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</table>

#### Materials, Supplies, Equipment, References, and Other Resources:
- BMP publications from the previous day (student work)
- Environmental Impacts handout (classroom set)
- Environmental Impacts Outline Guide (one per group)

#### Agriscience Foundations Standards:
1.04 - Examine the role of the agricultural industry in the interaction of population, food, energy, and the environment.
4.03 – Describe the environmental resources (soil, water, air) necessary for agriculture production.

#### Essential Question:
Why are some public organizations concerned about the agricultural industry’s impact on environmental resources?

#### Daily Objectives
1. Explain the impacts of agricultural practices on the environment.
2. Apply the impacts on the environment to specific BMPs designed to reduce impacts.

### Introduction (Interest Approach)

Assign student partners from the previous two days to role play as a certain type of agricultural producer. The producers can be related to various crop and/or livestock farms. Tell students that they have been working as a producer on that farm for years, and that their practices have been passed down from previous generations. Up to this point, their practices have not changed much because of the family traditions rooted in the farm’s practices. Give each student partner group a different group’s conservation publication from the previous day (it is fine if these are in draft form).

Instruct student groups to read the publications and consider their willingness to adopt best management practices based on the publications’ message. Hold a brief discussion when students are finished reading about how likely they would be to adopt BMPs.

*Guiding questions – Would you adopt the BMPs based on this article? How much do you think the average farmer knows about agriculture’s impact on the environment? Do you think farmers are concerned with their role in environmental conservation? How do you think farmers could be made more aware of their impact on environmental quality?*
Learning Activity 1

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Estimated Time: 25 minutes</th>
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</table>
| Explain to students that they will be developing a message for agricultural producers to inform them of agriculture’s impact on the environment in an effort to convince those that might be unwilling to adopt BMPs. In their partner groups from the previous two days, students will use the Agricultural Impacts handout to design their message. They can create a message in any format they feel is appropriate for the audience (agricultural producers) that is approved by the teacher. Possible message formats include:  
- Powerpoint  
- Brochure  
- Video/Commercial  
- Newsletter  
- Business letter  
- Speech  
- Etc.  
Students should use this time to determine their message format and create an outline of the content they want to include in their message following the Environmental Impacts Outline Guide. Guides should be kept and turned in during the following class. They should be completely ready to produce their messages by the end of the class. Teachers should monitor student progress and approve message formats by walking around to each group and asking questions about the group’s plans for their message.  

*Guiding questions – Why are you choosing that message format? How does that content link to your publication’s BMPs?*

<table>
<thead>
<tr>
<th>Brief Content Outline</th>
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| 1. Water Quality  
2. Land Quality  
3. Air Quality |

<table>
<thead>
<tr>
<th>Summary (Review)</th>
<th>Estimated Time: 5 minutes</th>
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<tbody>
<tr>
<td>Tell students that they will be designing their messages during the following class. The teacher should make sure that all supplies needed for each message to be developed is available to the students for the following class.</td>
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<tr>
<th>Evaluation</th>
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<tr>
<td>Students will be evaluated through teacher questioning and their outline guides, which will be turned in during the following class.</td>
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</table>
Environmental Impacts

You already know how agriculture uses environmental resources and how they can use certain practices to improve resource quality. But how do agricultural practices impact resources? Find out below…

Water Quality

- Agriculture is leading source of water impairments in nation’s rivers and lakes
- 25,823 bodies of water (streams, lakes) are impaired nationwide
- 71% of US cropland is located in watersheds where pollutant concentration is above accepted levels for water-based recreation
- Structural changes in animal agriculture between 1982 and 1No7 increased levels of fecal coliform bacteria in the Great Plains, Ozarks, and Carolinas.
- Almost half of the wetlands in the nation have been drained during the nation’s history, most for agricultural use
- Sediment, nutrients, pathogens, pesticides, and salts enter water sources
- Sediment – largest contaminant of surface water, second leading pollution problem in rivers and streams. Results from soil erosion (from soil composition and agricultural production practices)
- Nutrients – nitrogen and phosphorus are applied to cropland as crop nutrients as fertilizer and manure applications. Enter water sources through runoff and leaching. Promotes algae growth (eutropication), which leads to lower oxygen levels, kills fish, clogs pipelines, and reduces recreations opportunities. Nitrogen pollution leading cause of water quality impairment in lakes. 9% of domestic wells during 1No3-2000 had nitrogen concentrations above EPA’s drinking water standards.
- Pesticides – can damage freshwater and marine organisms, fisheries, drinking water, and recreational water activities. Pesticides were found in low concentrations in 37% of groundwater sites examined in a national water quality assessment
- Salts – from excess irrigation that runs off of fields. Reduces crop yields, damages soil, increase water treatment costs
- Pathogens – bacteria are largest source of impairment in rivers and streams. From poorly treated human waste, wildlife, and animal feeding operations. Diseases can be transmitted through contact with contaminated water, or consumption of contaminated shellfish. Diseases commonly found in animals can be transmitted to humans (zoonoses)
- Contaminants enter water sources through runoff and leaching
Land Quality

- Disturbing the soil harms soil microbes, which help keep nutrients and water in the soil.
  - Physical disturbance – tilling
  - Chemical disturbance – misuse of inputs, like fertilizers and pesticides
- Planting the same crop over and over again robs the soil of the same nutrients repeatedly without replenishing them.
- Leaving fields bare reduces amount of nutrients in the soil
  - Causes water to leach nutrients out of soil
  - Causes erosion of soil
  - Reduces nutrient input back into soil from decomposing plant matter
  - Certain organisms begin shredding crop residues into smaller pieces, and can increase nutrient cycling by 25%. If there is no residue, there is no habitat for these organisms.
- Number of U.S. farms selling hogs decreased by 94% between 1959 and 2002, while hog sales more than doubled. Similar trends have occurred among farms selling dairy products, cattle, and broilers. As livestock producers expand, they are more likely to buy feed grown elsewhere, reducing the amount of land they have available for manure application, the predominant method of disposal.
- Livestock production doesn’t pose a problem if farms have enough land to spread manure, but many livestock producers don’t spread manure to their land, or may spread more manure than crops need on the fields closest to the facility (lowers hauling cost). Some counties have more livestock manure than they do appropriate land to spread it to meet land needs.

Air Quality

g. Livestock farms are responsible for 18% of all greenhouse CO2 emissions, 64% of ammonia emissions, 65% of nitrous oxide, and 37% of methane worldwide
  i. Makes it difficult for states to meet Clean Air Act standards
  ii. Many compounds released by animal production cause unpleasant odors and issues with comfort, health, and production efficiency of animals and humans
1. Swine manure produces organic sulfur compounds (rotten egg smell), which can cause unconsciousness or death in high concentrations
2. Application of manure to croplands and pasture increases nitrous oxide, which is 3 times more effective in trapping heat in the atmosphere than carbon dioxide. Ag. industry (both cropland and animal production) account for 72% of nitrous oxide emissions in US
3. Methane comes from ruminant animals (cattle, buffalo, sheep, goats) during digestion. Also released from liquid manure holding areas (lagoons or tanks). Livestock production accounts for 37% of total global methane emissions
Environmental Impacts Outline Guide

1. In what format do you plan on producing your message?

2. Why do you feel this is an appropriate form for your audience?

3. How will you create interest in the beginning of your message?

4. What facts regarding agriculture’s impact on the environment will you include in your message?

5. What made you select these facts over the others?

6. Why do you feel these facts are especially impactful or important?
7. How will you design your message to be appealing to the audience?

8. How will you design your message to be professional?

9. How will you design your message to cause a change in behavior?

10. Based on your message format, draw or outline a rough draft of your message below. For example, if your message is a brochure, draw it out. If your message is a speech, outline what you will say.
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<thead>
<tr>
<th>Daily Plan</th>
<th>Socio-Scientific Issues Instruction – Day 21</th>
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<tbody>
<tr>
<td><strong>Lesson Title:</strong></td>
<td>Informing Agricultural Producers – Message Creation</td>
</tr>
<tr>
<td><strong>Unit Title:</strong></td>
<td>Environmental Impacts</td>
</tr>
<tr>
<td><strong>Course:</strong></td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>45 minutes</td>
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</table>

**Materials, Supplies, Equipment, References, and Other Resources:**
All materials required by students to develop messages in formats approved by the teacher during the previous class. Outline Guides from the previous day

**Agriscience Foundations Standards:**
1.04 - Examine the role of the agricultural industry in the interaction of population, food, energy, and the environment.
4.03 – Describe the environmental resources (soil, water, air) necessary for agriculture production.

**Essential Question:**
Why are some public organizations concerned about the agricultural industry’s impact on environmental resources?

**Daily Objectives**
1. Create messages designed to inform agricultural producers of their impacts on the environment.
2. Evaluate the effectiveness of messages designed to inform agricultural producers of their impacts on the environment.

**Introduction (Interest Approach)**
Estimated Time: 5 minutes

Have students get into their partner groups and collect their materials to produce their messages.
<table>
<thead>
<tr>
<th>Learning Activity 1</th>
<th>Estimated Time: 25 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>Students should begin producing their messages immediately based on their outlines from the previous class. During this time, the teacher should monitor student progress by walking around the groups, asking questions and assisting as needed.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Learning Activity 2</th>
<th>Estimated Time: 10 minutes</th>
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</thead>
<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>Student partner groups will trade messages with one another. All groups should receive the message that was produced by the group whose publication they evaluated during the beginning of the previous class. Groups should evaluate the message based on the role they took on when evaluating the publication, evaluating whether the information provided in the message and the message itself would convince them to consider adopting BMPs. Classroom discussion should follow, focusing on how messages might impact producer practices and aspects of messages that might be more impactful than others. Both the outline guides and messages should be turned in upon completion of the discussion.</td>
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</table>

<table>
<thead>
<tr>
<th>Summary (Review)</th>
<th>Estimated Time: 0 minutes</th>
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<tbody>
<tr>
<td>The summary of this lesson is combined with Learning Activity 2.</td>
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</table>

<table>
<thead>
<tr>
<th>Evaluation</th>
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</thead>
<tbody>
<tr>
<td>Students will be evaluated on their messages and their outline guides.</td>
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<table>
<thead>
<tr>
<th>Items Students Turn In</th>
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</thead>
<tbody>
<tr>
<td>Outline Guides</td>
</tr>
<tr>
<td>Student-created Messages</td>
</tr>
</tbody>
</table>
Introduction (Interest Approach)  |  Estimated Time: 10 minutes
---|---
Have students consider the information they learned about the agriculture industry’s impact on the environment and best management practices. Hold a class discussion about whether the students think the industry “pulls its weight” in environmental conservation, or if its practices do more harm to the environment than it can currently make up for.

*Guiding questions* – *Do you think the agriculture industry’s practices are more harmful to the environment than they are helpful? Do you think the use of BMPs contributes to environmental conservation enough to alleviate the concerns of individuals? Are current agricultural practices capable of maintaining an acceptable level of environmental quality, or do more sustainable practices need to be developed?*
Learning Activity 1

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Estimated Time: 25 minutes</th>
</tr>
</thead>
</table>
| Give each student an index card and instruct them to draw a happy face on one side and a sad face on the other. Explain to the students that the class will be evaluating some agricultural practices that may impact the environment. Students will take notes on the practices using the attached Environmental Evaluation Sheet while the teacher introduces the content through the Environmental Impacts powerpoint. After each practice is introduced, students will evaluate their notes and hold up their index cards, showing the happy side if they feel practice helps alleviate environmental concerns and the sad side if they feel the practice contributes to environmental concerns. Students should hold up an empty hand if they feel the practice has no impact on the environment. After students hold up their cards, briefly ask students to explain why they feel practice enhances or hinders environmental quality. | Beef Industry -  
  i. Feeding  
  ii. Housing  
 Swine Industry –  
  i. Housing  
 Poultry Industry –  
  i. Feeding  
  ii. Housing |

**Guiding questions** – Why do you think that practice hinders/enhances environmental quality? Do you think the practice is necessary, despite its environmental impacts? Do you think the practice sufficiently alleviates public concerns, or should more be done? What else do you think could/should be done to minimize that environmental impact?

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Summary (Review)

<table>
<thead>
<tr>
<th>Estimated Time: 10 minutes</th>
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<tbody>
<tr>
<td>Ask students how they think the production of cultured meat would impact environmental quality and environmental concerns. Using their notes, student should defend their comments by stating how cultured meat production would eliminate or alter agricultural practices and environmental concerns.</td>
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</tbody>
</table>

**Guiding questions** – What types of environmental concerns might cultured meat bring up or contribute to? What types of environmental concerns might cultured meat alleviate? What current practices would be altered or eliminated if cultured meat was produced? How would this impact environmental quality in the long term future?
<table>
<thead>
<tr>
<th>Evaluation</th>
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<tr>
<td>Students will be evaluated based on their discussion throughout the class.</td>
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<table>
<thead>
<tr>
<th>Items Students Turn In</th>
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<tbody>
<tr>
<td>None.</td>
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</table>
Environmental Evaluation Sheet

Using the chart below, record meat production practices, then evaluate how they might impact the environment.

<table>
<thead>
<tr>
<th>Beef Industry Practices</th>
<th>😊/😊/😊</th>
<th>Reasons for Evaluation</th>
</tr>
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<tbody>
<tr>
<td>Feeding Practices:</td>
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<tr>
<td>Swine Industry Practices</td>
<td>😊😊😊</td>
<td>Reasons for Evaluation</td>
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<tr>
<td>Housing Practices:</td>
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<table>
<thead>
<tr>
<th>Poultry Industry Practices</th>
<th>😊😊😊</th>
<th>Reasons for Evaluation</th>
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<tbody>
<tr>
<td>Feeding Practices:</td>
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| Housing Practices:         |       |                        |
|                            |       |                        |
|                            |       |                        |
|                            |       |                        |
|                            |       |                        |

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Meat Production Practices
How do they impact the environment?

The Beef Industry
• Housing
  – Mature cows need a sheltered place or windbreak
  – Well drained to keep mud minimal
  – Newborn calves should have access to a portable shelter if born in winter
  – Finishing cattle can be fed in small groups indoors on a manure pack
  – Larger feedlots are entirely outdoors, contain a windbreak for shelter and high dry place for cattle to lie

Are things always as they seem?
• Agricultural practices can look environmentally unsound – are they?
  – Use your notes and √/x cards to evaluate the following meat production practices

The Swine Industry
• Housing
  – In temperate climates, can be raised outside
  – In northern states, pigs have access to warm, dry, well-bedded shelter to keep out of cold weather
  – Amount of feed must be increased if pigs are left in cold without shelter
  – Growth rates slow if temp gets below 60-65
  – Sows are farrowed in temperature controlled buildings
  – Heat is more harsh on a pig than cold, so feed rate slows above 80-85.
  – Pigs have no sweat glands or any natural way to cool off
  – Sprinkler systems can drip water onto pigs for cooling or outdoor facilities should have shade and access to a wet place to lie down

The Beef Industry
• Feeding
  – Rotational grazing
  – 1-1.5 acres can support a cow/calf pair for an entire year
  – In drier climates, a cow/calf pair can require up to 130 acres
  – Dry, pregnant cows get stored forages in winter (ex – hay)
  – Bulls are fed stored forages when not breeding. Require grain before, during, and after breeding to maintain body condition
  – All have access to free-choice salt and minerals
  – Finishing cattle (feedlot cattle) get high-grain, high-energy diet, very little forage. Results in rapid gains and increased carcass quality. Young feedlot cattle receive supplemental protein
  – Silages are substituted for grain in low-energy finishing diets

The Poultry Industry
• Feeding
  – Feed costs are 2/3 of total cost of producing meat from chickens
  – Grains make up 50-80% of total feed ration
  – Rest of feed is protein, vitamins, fats, additives, grit (often granite particles) to help chew b/c they don’t have teeth. Doesn’t have high need for roughages b/c doesn’t have a rumen to digest them like cattle
  – Free choice eating because chickens will eat enough to meet energy requirements
The Poultry Industry

- **Housing**
  - Raised in confinement in an open-floor system
  - House is cleaned and disinfected each time a flock leaves, wait one week for new flock to come in
  - New litter is put into house for new flock
  - Floor space per bird is increased with age (half of the house may be blocked off until chickens reach 20 weeks)
  - Use lights 24 hours per day
  - Temps should be controlled
    - Chicken behavior can indicate whether they need more or less heat
    - Huddling together and cheeping or moving away from the heater
  - Ventilation will prevent respiratory diseases and will reduce ammonia odor

Do you know of any others?

- What other practices do you think impact the environment?
Have students get into groups of three. This can be done via the teacher’s preference based on the activity (see Learning Activity 1). Explain to the students that they will be debating whether the agricultural industry’s current practices do enough to maintain environmental quality while producing needed products. Each student in the group should be given one of the following roles:
- Pro current agricultural practices
- Anti current agricultural practices
- Judge

Have each student gather their notes from the previous five days, including agricultural practices, environmental impacts, BMPs, and the environmental resources used by the agriculture industry. These will be used to help them support their sides during their debates.
Learning Activity 1

<table>
<thead>
<tr>
<th>Estimated Time: 30 minutes</th>
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<tbody>
<tr>
<td>Instructor Directions / Materials</td>
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</table>

**Brief Content Outline**

- Explain debate rules to students:
  - Two students in the group will be debating, using their notes to help them support their point. During each turn, the student can make one point related to their side.
  - Students assigned the role of “pro current agricultural practices” will be arguing that current agricultural practices sufficiently conserve the environment, and that practices should not be further altered.
  - Students assigned the role of “anti current agricultural practices” will be arguing that current agricultural practices contribute unnecessarily to environmental harm and that practices should be further altered to alleviate environmental concerns.
  - Students assigned the role of “judge” will be responsible for giving points to each debater based on their ability to state new supporting evidence on each turn. The judge should keep in mind that each piece of supporting evidence should be new, relate to agricultural practices and the environment, accurate, and have a connection with the debater’s position. The judge should use his/her notes to validate the arguments offered by each debater, and should keep track of the points awarded.
  - Students debating should take turns offering statements back and forth until one student runs out of arguments, or until one student reaches 20 points according to the judge.

**Summary (Review)**

<table>
<thead>
<tr>
<th>Estimated Time: 10 minutes</th>
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</thead>
<tbody>
<tr>
<td>As a class, have students verbally reflect on their debate.</td>
</tr>
</tbody>
</table>

Guiding questions – Do you think that agricultural practices are sufficient in maintaining or improving environmental quality? Can any other practices improve environmental quality? Were your arguments easy to develop? Were the arguments easy to judge? How did you determine which practices supported your side? How did you determine whether the offered argument was worth a point? Which side won in your group?

**Evaluation**

Students will be evaluated based on discussion at the end of class.

**Items Students Turn In**

None.
### Daily Plan

<table>
<thead>
<tr>
<th>Lesson Title:</th>
<th>The Role of Organizations in Environmental Conservation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Title:</td>
<td>Environmental Impacts</td>
</tr>
<tr>
<td>Course:</td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>45 minutes</td>
</tr>
</tbody>
</table>

### Materials, Supplies, Equipment, References, and Other Resources:
- Computer linked to a projector with internet access
- Farming on a Refuge Video ([http://www.youtube.com/watch?v=hHVo4By2vug](http://www.youtube.com/watch?v=hHVo4By2vug)). *Note – also available on dropbox.*
- Regulation of Agricultural Practices powerpoint
- Regulation of Agricultural Practices sheet (classroom set)

### Agriscience Foundations Standards:
- 1.04 - Examine the role of the agricultural industry in the interaction of population, food, energy, and the environment.
- 4.03 – Describe the environmental resources (soil, water, air) necessary for agriculture production.
- 4.04 – Identify regulatory agencies that impact agricultural practices.

### Essential Question:
Why are some public organizations concerned about the agricultural industry’s impact on environmental resources?

### Daily Objectives
1. Identify the role of various organizations in monitoring the agricultural industry’s impact on the environment.
2. Evaluate the effectiveness of the current connection between BMPs and regulatory agencies.

### Introduction (Interest Approach) | Estimated Time: 10 minutes

Have students watch the video about farming on a national wildlife refuge ([http://www.youtube.com/watch?v=hHVo4By2vug](http://www.youtube.com/watch?v=hHVo4By2vug)). *Note – the video can be stopped when it starts talking about the family’s nonfarm activities.* After the video, ask students to consider how farming practices and their impacts on the environment are controlled. Glean student ideas and thoughts through a brief discussion. *Guiding questions – Who monitors the practices of the farmer in the video? What types of practices do they monitor? Do you think the farmer has to follow other practices as well? Why do you think these practices should be monitored – what impact do they have on the environment? What organizations do you think play a part in monitoring agricultural practices?*
### Learning Activity 1

**Estimated Time: 20 minutes**

**Instructor Directions / Materials**

The teacher should lecture about the organizations responsible for monitoring the agriculture industry’s practices using the Regulation of Agricultural Practices powerpoint. *Note – the NRCS video clip should be played from 3:54-6:21. It is also available on dropbox.*

During the lecture, students should write notes on the Regulation of Agricultural Practices sheet, which will help students link agricultural practices with environmental impacts.

**Brief Content Outline**

1. USDA – Natural Resources Conservation Service
2. EPA
3. FDA
4. States

### Learning Activity 2

**Estimated Time: 10 minutes**

**Instructor Directions / Materials**

In partners, have students examine their notes and determine if there are any gaps or problems they see in the monitoring of agricultural practices. Encourage students to focus on which items have laws and which items are regulated through optional programs.

During this time, the teacher should monitor group progress by asking questions to each group. *Note – the voluntary aspect of many organizations and regulations is an issue that should be focused on.*

*Guiding questions – Do you think there are any problems with the current regulation system? If not, are there any practices that go unregulated or any environmental impacts that are not addressed? If so, why do you think that’s a problem? What do you think can be done to alleviate that problem?*
<table>
<thead>
<tr>
<th>Summary (Review)</th>
<th>Estimated Time: 5 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discuss as a class the problems or gaps they noticed in the regulation of agricultural practices and potential solutions to address these. Guiding questions are similar to those in Learning Activity 2.</td>
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</table>

<table>
<thead>
<tr>
<th>Evaluation</th>
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<tbody>
<tr>
<td>Students will be evaluated on their discussions throughout the class.</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Items Students Turn In</th>
<th></th>
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<tbody>
<tr>
<td>None.</td>
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</table>
Regulation of Agricultural Practices

**USDA:**
- Stands for:
- Regulates through:
- Responsible for:
- Impact on Specific Agricultural Practices:

**EPA:**
- Stands for:
- Responsible for:
- Five Most Impactful Federal Acts Regulated (regarding agricultural practices):
- Not Responsible for:
- Impact on Specific Agricultural Practices:
FDA:
- Stands for:
- Responsible for:

- Impact on Specific Agricultural Practices:

States:
- #s:

- Impact on Specific Agricultural Practices:
Regulation of Agricultural Practices

Who's in Charge?

EPA
• Mission – protect human health and environment
• To accomplish mission, they:
  – Develop and enforce regulations after congress writes the law needing regulations
  – Give grants to state environmental programs and organizations engaging in environmental improvement projects
  – Study environmental issues
  – Educate others
  – Publish information

Four Entities Regulate Ag Practices
• USDA – United States Department of Agriculture
• EPA – Environmental Protection Agency
• FDA – Food and Drug Administration
• States – authority given to the states by the federal government

USDA
• Regulates through the Natural Resources Conservation Service (NRCS)
• What does NRCS do?
  – Agricultural Management Assistance – provides money to ag. producers who voluntarily address issues such as water quality and management, erosion control, etc. by incorporating conservation into their farming operations

EPA
• Federal Acts Regulated:
  – Safe Drinking Water Act
  – Clean Water Act
  – Federal Insecticide, Fungicide, and Rodenticide Act
  – Endangered Species Act
  – Toxic Substances Control Act
  – Resource Conservation and Recovery Act
  – Comprehensive Environmental Response, Compensation, and Liability Act
  – Clean Air Act
  – Emergency Planning and Community Right to Know Act
  – Food Quality Protection Act
  – Oil Pollution Act

EPA
• They don’t handle items that are the responsibility of the state or other federal agencies
  – Endangered Species Act – US Fish and Wildlife
  – Nuclear waste – Dept. of Energy
  – Destruction of wetlands – US Army Corps of Engineers
  – Insecticide, Fungicide, Rodenticide Act – FDA
  – Farming in your area – Local Extension Office
  – Noise pollution – state regulations (although EPA used to regulate this!)
FDA is responsible for:
- Assuring that foods are safe, wholesome, sanitary and properly labeled
- Human and veterinary drugs, and vaccines biological products and medical devices are safe and effective
- Protecting the public from electronic product radiation
- Cosmetics and dietary supplements are safe and properly labeled
- Regulating tobacco products
- Helping to speed product innovations
- Helping the public get the accurate science-based information they need to use medicines, devices, and foods to improve their health
- Assessing environmental impacts associated with its actions and approvals of all the above-mentioned items (required to do so through National Environmental Policy Act)

States
- No nationwide monitoring programs in US to calculate agricultural emissions of greenhouse gases
- 33 states have laws that regulate agricultural use of water and water quality
- Many states use standards to employ best management practices (conservation tillage, nutrient management, pesticide management, irrigation water management)
<table>
<thead>
<tr>
<th>Daily Plan</th>
<th>Socio-Scientific Issues Instruction – Day 25</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lesson Title:</strong></td>
<td>Environmental Concerns Evaluation</td>
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<tr>
<td><strong>Unit Title:</strong></td>
<td>Environmental Impacts</td>
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<tr>
<td><strong>Course:</strong></td>
<td>Agriscience Foundations</td>
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<tr>
<td><strong>Estimated Time:</strong></td>
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**Materials, Supplies, Equipment, References, and Other Resources:**
- Student notes from the entire Environmental Impacts unit
- Alliance for Better Foods Argument
- Sierra Club Argument
- Argument Validity Evaluation (classroom set)

**Agriscience Foundations Standards:**
1.04 - Examine the role of the agricultural industry in the interaction of population, food, energy, and the environment.
4.03 – Describe the environmental resources (soil, water, air) necessary for agriculture production.
4.02 – Describe various ecosystems as they relate to the agriculture industry.

**Essential Question:**
How could the use of GMOs impact environmental resources?
How is food safety impacted by production practices and animal health?

**Daily Objectives**
1. Describe the potential impacts of GMO use on the environment.
2. Evaluate the validity of various organizations’ claims regarding their views on the impact of GMOs on the environment.

**Introduction (Interest Approach)**

Explain to students that for the past several weeks, they have learned about how current agricultural practices impact the environment.
Ask for a show of hands that indicates whether students feel that more needs to be done to protect the environment against harmful agricultural practices or if current agricultural practices are sustainable with regard to maintaining or improving environmental quality.

After this show of hands, ask students whether they think the production of cultured meat and other GMOs would have an impact on the environment. This can be done again using a show of hands.
### Learning Activity 1

**Estimated Time: 10 minutes**

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Brief Content Outline</th>
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</thead>
</table>
| In groups of 2-3, have students create a brainstorming list of concerns and benefits that could result from the production of GMOs. Share these lists through a method of the teacher’s choice. Potential options include:  
- Large pieces of paper around the room where students write their ideas for benefits and concerns, which are then discussed as a class  
- Brief group presentations  
- Open class discussion with teacher writing ideas down on the board  
- Etc.  
As lists are shared, the teacher should make sure that the concerns and benefits listed include those in the content outline (p. 7). During discussion, encourage students to carry their ideas to long term or indirect impacts as well.  

*Guiding questions – Do you think that concern/benefit is a legitimate one? Do you think that concern/benefit might be offset by other benefits/concerns? Why do you think that is a benefit/concern? How could it impact aspects of the environment? How could that impact then affect other areas, like humans or the economy?* |
| 1. Concerns –  
  a. Risk of accidentally introducing engineered genes into wild populations  
     i. Can alter wild organisms, ecosystems  
  b. Persistence of the gene after the GMO has been harvested  
     i. Crop residues  
  c. Susceptibility of non-target organisms to the gene  
     i. Insects which are not pests could be harmed  
  d. Stability of the gene  
     i. Does it remain as is, or does it get altered into something unwanted (ex - cancer)  
     ii. Loss of biodiversity  
     iii. Increased use of chemicals in agriculture  
  e. Pest resistance to gene – does it build up over time?  
  f. Potential generation of new pathogens  
  2. Potential Benefits –  
  a. Reduced chemical and mechanical needs in planting, maintenance, harvest  
     i. Reduced chemical pollution, maintained soil composition, less erosion  
  b. Can increase land availability through use of previously unusable land (drought, flood, extreme weather) |
**Learning Activity 2**

**Estimated Time: 20 minutes**

**Instructor Directions / Materials**

Have students gather their notes from the entire Environmental Impacts Unit for use in this activity. Explain to students that with the help of these notes, they have become experts in understanding how agricultural practices impact the environment. However, some organizations might try to convince people to agree with their point of view by “educating” them with inaccurate information. As experts, these students are now able to evaluate the claims made by organizations to determine whether they are valid and justified or unfounded and false.

Arrange students in groups of 2. Give each group one copy of the Alliance for Better Foods Argument and one copy of the Sierra Club Argument. Each group should also receive two copies of the Argument Validity Evaluation sheet (one for each student). Have each student use the sheet to evaluate one of the arguments.

**Brief Content Outline**

When students are finished evaluating the argument, they should discuss the argument’s validity with their partner, and each partner should make a final position statement based on their views of the arguments and their knowledge of environmental impacts. These are to be written on the bottom section of the Argument Validity Evaluation sheet. The sheet should be turned in upon leaving the class.

**Evaluation**

Students will be evaluated based on the Argument Validity Evaluation sheet.

**Items Students Turn In**

Argument Validity Evaluation sheet
Argument Validity Sheet

Name ______________________________

Instructions: Using the guiding statements below, evaluate the argument of one organization. Then, after listening to your partner’s assessment of the other organization’s argument, determine your position regarding the validity of each organization’s argument and the impacts of agricultural practices on the environment.

Organization:

Statements I think are true:

Statements I think are false:

Evidence from my notes:

Evidence from my notes:

How I feel about this organization’s overall argument:

How I feel about agriculture’s overall impact on the environment:
Environmental Impacts Argument
Organization: Alliance for Better Foods

Some biotech crops are already beginning to improve the environmental performance of agriculture, and future crops may eventually make significant global contributions to the preservation of valuable forestlands in the developing world. Following are anticipated environmental benefits from food biotechnology.

Conservation of natural resources
Hardier disease- and pest-resistant crops can allow greater conservation of resources by requiring less fuel, labor, water and fertilizer. For example, international researchers in Georgia and Israel are exploring ways to produce cotton that can survive in semi-arid conditions, a development that could one day lead to a savings of some 12 billion gallons of water a year.

Less land use
Researchers around the world are developing hardier strains of fruits, vegetables and grains that one day may be able to thrive in extreme growing conditions such as tomatoes that can flourish in high-salinity soils. Other plant varieties that can protect themselves from pests and diseases mean that growers will be able to produce more food on the same amount of land, thereby reducing pressures to clear additional acres for cultivation. According to the National Council on Food and Agricultural Policy, improved farm productivity could result in less impact on prairies, wetlands, forests and other fragile ecosystems that might otherwise be converted for agricultural purposes.

Less pesticide use
Biotech crops can reduce the use of agricultural chemicals such as insecticides and fungicides. Scientists have developed strains of corn and cotton that produce their own protection against specifically targeted pests, thus reducing the amount of pesticides necessary to control them. In addition, herbicide tolerant varieties of many crops have been developed. According to a study by the National Center for Food and Agricultural Policy (NCFAP), U.S. pesticide use was 45.6 million pounds lower in 2001 than it would have been without the use of biotech crops. The use of herbicide tolerant soybeans reduced pesticide levels by 28.7 million pounds, while herbicide tolerant cotton helped cut pesticide levels by 6.2 million pounds. Another report by NCFAP notes several studies finding that growers are achieving higher yields and attaining higher profits by planting Bt varieties of crops, due to the better pest control and decreased pest control costs they provide.
Environmental Impacts Argument
Organization: Sierra Club

SUPERWEEDS: GE crops were first planted in the mid 1990s. Already, research has documented that genes producing desired characteristics in crops can confer adaptive advantages to weedy species, causing problems in valuable wild plant habitats. Research suggests that bees may be important pollen vectors over a range of distances and farm-to-farm spread of oilseed rape transgenes will be widespread. Pollen can also travel for miles in the wind and integrate its DNA into the genome of conventional plants. Genes from GEOs (genetically engineered organisms) can spread to wild plants and native species, resulting in herbicide resistant superweeds. For example, the pollen from transgenic rapeseed (canola) can blow into neighboring farms and wild areas and can easily outcross to any nearby canola plant. The herbicide resistant traits become promiscuous and transfer to weedy relatives. The traditional weed then becomes a stronger "superweed." This outcrossing has started to produce superweeds that are resistant to a wide range of herbicides. The 4/26/00 edition of New Scientist magazine reported the first officially confirmed case of its kind: weeds in Canada which became resistant to three kinds of herbicides: Roundup, Liberty and Pursuit. It only took three years for a transgenic spread of super-herbicide-resistance. The rapid outcrossing of GEO herbicide resistant plants raises serious questions for those concerned about the emergence of weeds that do not die no matter what herbicide is applied. These superweeds may very well have a bioengineered advantage in taking over farm fields and in moving through wild areas, where they are likely to have a range of impacts on populations of wild plants and wild plant habitats.

BIODIVERSITY: In the 9/18/No Worldwatch Institute report "Farmers Losing Seed Varieties Worldwide," John Tuxill wrote that in the United States more than 80% of seed varieties sold a century ago no longer are available and that the world is rapidly losing genetic diversity in crops. With development of transgenic crops, traditional varieties may dwindle even further as farmers grow a less diverse pool of crops to obtain the highest yields for commercial production. Bt (Bacillus thuringiensis) toxins are becoming ubiquitous, highly bioactive substances in agroecosystems. Bt crops are pumping out huge amounts of toxin from all tissues throughout the growing season, from germination to senescence. Most non-target herbivore insects, although not lethally affected, ingest plant tissue containing Bt protein which they can pass on to their natural enemies. There are also unanticipated effects on non-target insects through deposition of transgenic pollen on foliage of surrounding wild vegetation. These effects herald problems for small farmers in developing countries and for organic farmers since they rely on insect pest control. For instance, loss of lady bugs and lacewings will likely result in increased crop losses. The Soil Association report (UK) on 6/22/No warned, "GM code could wipe out wildlife." Birds, for instance, might lose habitat and major food sources (both plants and insects). The spread of transgenics into the wild and the effect this will have on biodiversity may be especially severe in less developed countries and wherever native archetypal varieties of agricultural crops exist.

SOIL FERTILITY: The soil food web is crucial for plants to obtain the nutrients necessary for growth. Many crops are engineered with the Bt toxin in order to resist infestation from insects. Yet root exudates from these plants release the toxin into the soil, where it retains its activity for at least 234 days, long after its release. This stimulates major changes in soil biota that could affect nutrient cycling.
processes and reduce soil fertility. Monsanto's advertising campaigns try to convince people that Roundup is safe, but the facts do not support that conclusion. Independent scientific studies have shown that Roundup is toxic to earthworms, beneficial insects, birds and mammals (in addition to destroying the vegetation on which they depend for food and shelter). The Progressive Farmer on 1/3/01 reported a University of Missouri study which revealed that Roundup Ready soybeans receiving glyphosate at recommended rates had significantly higher incidence of Fusarium on roots compared with soybeans that did not receive glyphosate. Fusarium is one of the most economically important groups of fungi causing diseases on a wide variety of plants. Pat Donald, professor and director of the UM nematology lab was quoted as saying "We're concerned because SDS (sudden death syndrome) is showing up everywhere and can be devastating."

**EFFECTS ON NON-TARGET INSECTS:** Insects have their place in the ecosystem. Some play a major role in maintaining the equilibrium of insect populations and are important for pest control strategies. The Bt toxin has been shown to be lethal to non-target organisms such as Monarch butterflies, lacewings and ladybird beetles. The issue is broader than whether Bt toxin produced by genetically modified crops imperils beneficial insects. The real issue is that a strategy to establish expression of an insecticidal compound in large-scale crop monocultures and thus expose a homogeneous sub-ecosystem continuously to the toxin can cause irreparable damage to natural habitats forever.

**SUSTAINABLE AGRICULTURE AND ORGANIC FARMING THREATENED:** There are many alternative approaches that farmers can use to effectively regulate insect and weed populations, i.e. rotations, strip-cropping, biological control, cover crops, and green manure. To the extent that transgenic crops further entrench the current system, they impede farmers from using a plethora of alternative methods. The entire future of organic farming is being threatened because pollen transfers by insects and the wind from GE crops to organic farms. Cross pollination can move transgenes into the crops so that, against their intentions, farmers are growing GE crops. GE seeds can also fall off trucks and farm machinery during transport or be left in the ground, leading to the growth of stray plants. It isn't debatable if Bt resistance will develop among insects populations, the question is how fast this will occur now that the toxins are being used in huge amounts throughout the entire growing season. Bt microbes are applied by organic farmers as a surface agent (when one is absolutely necessary) and will become ineffective as an important biological insect control tool. The problem of crop contamination not only has direct consequences for organic farmers; it also may damage our heritage of agricultural varieties, which has huge implications for populations around the world. For thousands of years, humans have selected and bred varieties adapted to unique climatic zones and regional properties. Transgenes may cause significant damage to that genetic diversity, and commercialization of a few varieties of patented seeds will also erode this vital heritage. "Terminator" systems designed to protect seed companies' profits by ensuring that farmers can't save seed (the succeeding crop will be sterile) are a further step away from sustainable agricultural practices and respect for the diversity of our agricultural heritage.

**GENE TRANSFER INTO GUTS OF BEES:** A three year study by a professor at the Institute for Bee Research, University of Jena found a gene transfer from GE rapeseed to bacteria and fungi in the gut of honey bees. Beatrix Tappesser from the Ecology Institute in Freiburg was quoted as saying "This is very alarming because it shows that the crossover of genes takes place on a greater scale than we had previously assumed. The results indicate that we must assume that changes take place in the intestinal tubes of people and animals. The crossover of microorganisms takes place and people's make up in terms of microorganisms in their intestinal tract is changed. This can therefore have health consequences."
### Daily Plan

<table>
<thead>
<tr>
<th>Lesson Title:</th>
<th>Environmental Impacts Posttest</th>
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</thead>
<tbody>
<tr>
<td>Unit Title:</td>
<td>Environmental Impacts</td>
</tr>
<tr>
<td>Course:</td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>45 minutes</td>
</tr>
</tbody>
</table>

### Materials, Supplies, Equipment, References, and Other Resources:

- Question wall (this should be posted from the Day 1)
- Environmental Impacts Posttest (classroom set)

### Agriscience Foundations Standards:

1.04 – Examine the role of the agricultural industry in the interaction of population, food, energy, and the environment.
4.03 – Describe the environmental resources (soil, water, air) necessary for agriculture production.
4.02 – Describe various ecosystems as they relate to the agriculture industry.
4.05 – Apply Best Management Practices that enhance the natural environment.
4.04 – Identify regulatory agencies that impact agricultural practices.

### Essential Question:

How does the agricultural industry use environmental resources?

### Daily Objectives

1. Demonstrate knowledge of agricultural practices and their impact on the environment.
2. Evaluate class progress on question responses for the unit.

### Introduction (Interest Approach)

Estimated Time: 5 minutes

Explain to students that they will be taking the Environmental Impacts Posttest.
<table>
<thead>
<tr>
<th>Learning Activity 1</th>
<th>Estimated Time: 15 minutes</th>
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</thead>
<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>Students will complete the Environmental Impacts Posttest. (Test Code: EN) Standard testing procedures should be enforced. Tests should be turned in upon completion.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Learning Activity 2</th>
<th>Estimated Time: 15 minutes</th>
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<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>Have students individually examine the question wall that they posted during the first lesson. <em>Students may have to leave their seats to read the questions.</em> On a sheet of paper, the students should write down the questions they feel have been answered through the past several weeks. <em>Note – if students have difficulty doing this because of the nature of the questions, allow them to select questions that they feel more comfortable answering, even if they do not feel the question is completely answered.</em> Once they have the questions written down, have them go back to their seats and write down answers to the questions.</td>
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</table>

<table>
<thead>
<tr>
<th>Summary (Review)</th>
<th>Estimated Time: 10 minutes</th>
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</thead>
</table>
| As a class, discuss the questions that students feel could be answered, and allow students to share their answers. The teacher should remove the question cards that have been sufficiently answered, and should leave the ones that have not been fully answered yet.  
*Guiding questions – How many of you think this question can be adequately answered? What are some answers you have to that question? How might we find answers to these questions? What else do we need to know to answer that question?* |

<table>
<thead>
<tr>
<th>Evaluation</th>
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<tbody>
<tr>
<td>Students will be evaluated through their responses on the Posttest and the classroom discussion.</td>
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</table>

<table>
<thead>
<tr>
<th>Items Students Turn In</th>
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</thead>
<tbody>
<tr>
<td>Environmental Impacts Posttest</td>
</tr>
</tbody>
</table>
Introduction (Interest Approach) | Estimated Time: 10 minutes
---|---
Ask students whether they think scientists know the impacts of cultured meat on the environment, and how scientists might learn more about cultured meat’s impacts on the environment. Discussion should be guided to encourage students to consider the tentative nature of science (science changes as new results are found) and the idea that scientists have differing interpretations of results and do not always agree on the conclusions.

Guiding questions – Do scientists know whether cultured meat is better for the environment than conventionally produced meat? How would they go about learning more? How many and what types of studies do you think they would need to conduct? Do you think these studies would have limitations? Would all findings and conclusions be correct? What impact should scientists’ knowledge have on the decision to produce cultured meat?
Learning Activity 1  
Estimated Time: 25 minutes

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Brief Content Outline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explain to students that they will be learning about the current knowledge available on the environmental impacts of cultured meat by reading an article that was published by a scientist in Italy in September of 2010. The students are to act as reviewers of the article and be prepared to ask the article’s author follow up questions that will help them gain a better understanding of what is now known about the environmental impacts of cultured meat.</td>
<td></td>
</tr>
<tr>
<td>Arrange the students in groups of 2-3. Each group should receive copies of the article and copies of the Article Interpretation Guide (one per student).</td>
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</tr>
<tr>
<td>Using the guide, have student groups work through the article. <em>Note – the article is designed for a research audience and will be challenging for the students to interpret. The guide is designed to help students focus on specific items in the article, make decisions about what is important, and develop questions related to their interpretation of the article. Student monitoring and assistance is crucial for the success of this activity, as students may get frustrated with the increased cognitive level required by the activity.</em></td>
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</table>

Summary (Review)  
Estimated Time: 10 minutes

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<table>
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<tbody>
<tr>
<td>The teacher is to role-play as the article’s author. <em>Note – the teacher must have read the article and be prepared to answer questions.</em> Students are to act as reviewers and ask the “author” questions they have about the study to help them interpret the findings and evaluate the conclusions drawn. As a final reflection, students are to answer the last question on their guides, which asks them to take a position on the impact of cultured meat production on the environment. The guide should be turned in at the end of class.</td>
<td></td>
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</tbody>
</table>

Evaluation

Students will be evaluated through their guides and through their questioning throughout the class.

Items Students Turn In

Article Interpretation Guide
Article Interpretation Guide

Name __________________________

Instructions: This guide is designed to help guide you through the article you’re about to read. Complete each of the sections in order to better review the article.

Helpful hints for use throughout the article: Fill in the following abbreviations and a “hint word” that reminds you what it is. The first is done as an example for you.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Word</th>
<th>Hint Word</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHG</td>
<td>Greenhouse gas</td>
<td>Air pollution</td>
</tr>
<tr>
<td>LCA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FU</td>
<td></td>
<td></td>
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<tr>
<td>DM</td>
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</table>

Fill in the definitions in your own words to help you remember what these terms mean throughout the article. The first is done as an example for you. The blank boxes are for you to include words and hints that you may find in your reading.

<table>
<thead>
<tr>
<th>Word</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>In vitro meat</td>
<td>Cultured meat</td>
</tr>
<tr>
<td>Cyanobacteria</td>
<td></td>
</tr>
</tbody>
</table>

According to the introduction…

Why is cultured meat being produced?

What is the purpose of the paper?

According to the materials and methods…

Cultured meat production impacts three things that are going to be measured. What three things are being measured in this study?

When the researchers are measuring the environmental impacts caused by cultured meat production, how much meat are they saying is in one unit of meat?

What do the researchers say is the protein percentage in one unit of meat?
According to the first paragraph on page 2 and Figure 1…

What are cyanobacteria used for in cultured meat production?

Where do cyanobacteria come from?

Where are stem cells taken from in order to grow the meat?

What are the muscle cells (from the stem cells) placed on in order to get them to grow?

What are the four products of cultured meat production?

What two types of energy input are required for the process of cultured meat production? *Hint – not cyanobacteria hydrosylate*.

What two parts of the meat production process require energy?

According to the results and Table 2…

What are the four factors that use energy in cultured meat production?

Using Table 2 and the results, fill in the two pie charts below to indicate the proportion of overall energy used and greenhouse gas let off that each factor is responsible for.

Proportion of energy required

Proportion of greenhouse gasses let off

Which overall factors accounts for the greatest portion of energy used and greenhouse gas emissions let out?
Which of the overall factors accounts for the smallest percentage of energy used and greenhouse gas emissions let out?

**According to the discussion…**

Which lets off more greenhouse gasses – cultured meat or traditional meat production?

Which requires more land – cultured meat or traditional meat production?

The list below indicates the order of energy requirements for traditional meat industries from the industry requiring the most energy (top) to the industry requiring the least energy (bottom). Write in where cultured meat production falls in this list.

- Beef
- Lamb
- Pork
- Poultry

Where did the researchers find numbers to compare energy production rates of different industries?

The researchers write that “the energy input calculations of cultured meat production in this study are based on many assumptions, and therefore, have high uncertainty”. What should the reader do with this information (should this make the reader think differently about the results and conclusions)?

Do the researchers think the land use makes cultured meat production more or less favorable than traditional meat production?

What are two ways that the researchers think cultured meat production can improve wildlife conservation?

Why do the researchers think that transportation energy required by cultured meat production would be less than traditional meat production?
## Daily Plan

<table>
<thead>
<tr>
<th>Lesson Title:</th>
<th>Predicting the Process of Cultured Meat Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Title:</td>
<td>Animal Industry</td>
</tr>
<tr>
<td>Course:</td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>45 minutes</td>
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</tbody>
</table>

### Materials, Supplies, Equipment, References, and Other Resources:

- Animal Industry Pretest (classroom set)
- From Pig to Plate Worksheet (classroom set)

### Agriscience Foundations Standards:

- 6.04 – Compare the basic internal and external anatomy of animals.
- 3.07 – Investigate DNA and genetics applications in agriscience including the theory of probability.

### Essential Question:

- How would cultured meat be created?

### Daily Objectives

1. Describe the importance of the process of cultured meat production in making decisions regarding its use.
2. Predict the steps of cultured meat production.

## Introduction (Interest Approach)

<table>
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<th>Estimated Time: 10 minutes</th>
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Ask students why it might be important to know about how cultured meat is produced in order to make a decision as to whether or not its introduction into the nation’s food supply is a good idea. This should be an open discussion.

**Guiding questions** – What aspects of cultured meat production might matter to those with economic concerns? What about those with environmental concerns? What about those with animal welfare concerns? What about those with food safety concerns? What aspects of cultured meat production do you want to know about in order to make a more informed decision as to whether it’s a good idea?
Learning Activity 1

Estimated Time: 15 minutes

Instructor Directions / Materials
Brief Content Outline

Have students take the Animal Industry Pretest. Appropriate test conditions should be monitored by the teacher. Tests should be turned in upon completion.

Learning Activity 2

Estimated Time: 15 minutes

Instructor Directions / Materials
Brief Content Outline

Arrange students into pairs. Give each student one “From Pig to Plate” worksheet. Explain to students that they will be learning about how cultured meat is produced, but will first predict how the process occurs. Using the worksheet pictures, the student groups are to spend one full minute discussing what the first picture (with the ☐ next to it) looks like it is portraying, and what caption they think would accurately reflect the picture. After the minute is up, students are to spend 30 seconds writing their decided caption next to the picture. The next minute should be spent discussing the second picture, followed by 30 seconds to write in the caption. This pattern should continue until the final picture is reached.

Note – One full minute of discussion on each picture should be enforced by the teacher, who will keep time and tell students when time is up. Students should not work ahead – the discussion portion encourages in-depth reflection and inquiry.

Summary (Review)

Estimated Time: 5 minutes

Tell students to bring their From Pig to Plate worksheets to the following class. Teachers may collect worksheets if they would prefer. Explain to students that they will be comparing their captions at the beginning of next class, and then learning how the process of cultured meat production compares to their predictions.

Evaluation

Students will be evaluated on their pretests and on their predictions during the following class.
<table>
<thead>
<tr>
<th>Items Students Turn In</th>
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<tbody>
<tr>
<td><strong>Animal Industry Pretest</strong></td>
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</table>
FROM PIG TO PLATE
Researchers are adapting tissue engineering techniques to grow edible meat, in vitro.

1. Remove muscle
2. Grow muscle
3. Scale up growing
4. Add flavor
5. Add fat
6. Build muscle
7. Add flavor
8. Cook
9. EAT!

Introduction (Interest Approach)

Arrange students in partners from yesterday, and ask that all students have their From Pig to Plate worksheet. Through a classroom discussion, ask students to share their captions for the steps of the production of cultured meat. Have students compare their captions and focus on why they felt those captions were appropriate based on their knowledge of the process and the pictures they interpreted.

Guiding questions – What indicators from the picture made you create that caption? What about your knowledge about cultured meat made you create that caption? Does anyone have a caption that indicates something else is done at that step? Why do you feel your caption is accurate?
<table>
<thead>
<tr>
<th>Learning Activity 1</th>
<th>Estimated Time: 25 minutes</th>
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<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>Individually, have students read the “From Pig to Plate” article. During their reading, students should:</td>
<td></td>
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<tr>
<td>1. Compare their captions with the captions in the article and rewrite the captions on their worksheets in their own words to be more accurate.</td>
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<tr>
<td>2. Highlight items about the process they feel are not fully developed (these are items or steps that could be changed in the future as the process becomes more refined).</td>
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<tr>
<td>3. Highlight items about the process they feel would alleviate consumer concerns that have been brought up by traditional meat production. These should be highlighted in a second color.</td>
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<tr>
<td>4. Highlight items about the process they feel would cause or create consumer concerns. These should be highlighted in a third color.</td>
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*Note – Based on the students, the teacher may direct students to read the article first and then give them each analysis step above separately, or may give students all directions at once.*

<table>
<thead>
<tr>
<th>Summary (Review)</th>
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<tr>
<td>Through classroom discussion, go over student thoughts regarding the article to each of the four analysis items above. Discussion of the captions should be the least in-depth discussion, while the other three items should cause more in-depth discussion.</td>
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</table>

*Guiding questions – How did your predicted steps compare to the actual steps of the process? What parts of the process do you think are not fully developed? Why do you think these parts might change in the future? What parts of the process alleviate consumer concerns? What types of concerns are alleviated? What parts of the process create consumer concerns? What groups do you think would have these concerns? Are there any concerns you have with the process?*

<table>
<thead>
<tr>
<th>Evaluation</th>
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<tbody>
<tr>
<td>Students will be evaluated based on their class discussion.</td>
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<table>
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<tr>
<th>Items Students Turn In</th>
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<tr>
<td>None</td>
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</table>
Introduction (Interest Approach) | Estimated Time: 10 minutes
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On the classroom computer/projector, access the cultured meat virtual taste test (http://www.pbs.org/wgbh/nova/tech/taste-test.html). Have students read through each of the “senses” (at the top of the screen). Note – this can be done aloud by selected students or silently as a group. Discuss student reactions after each of the senses, and take a poll at the end of the taste test about whether students would eat cultured meat.

Guiding questions – Based on what the taste test says about texture, do you think it’s possible for cultured meat to resemble traditionally grown meat? What about smell, look, or taste?
<table>
<thead>
<tr>
<th>Learning Activity 1</th>
<th>Estimated Time: 20 minutes</th>
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</thead>
<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>Students will use the Favorable Meat Characteristics sheet to predict the characteristics of traditional meat that would be difficult for scientists to reproduce in cultured meat, and the reasons for these difficulties. Notes for the sheet will be gathered from teacher lecture, using the Favorable Meat Characteristics powerpoint. Predictions can be discussed by the class throughout the lecture. <strong>Note – The teachers should guide these predictions using his/her knowledge as well.</strong> For example, marbling would be a barrier because cultured meat only uses muscle cells; physiological age of cells might be different from age of animal; any qualities (like color) from other cells (like blood) are not present. <strong>Guiding questions – Do you think this quality would be able to be produced in cultured meat? Why/why not? What aspects of the production of cultured meat make this quality difficult to obtain?</strong></td>
<td>Characteristics of traditionally harvested meat – 1. Beef 2. Pork 3. Poultry Characteristics/Barriers of Cultured Meat – 1. Texture 2. Flavor 3. Marbling/Fat 4. Color 5. Inclusion of various nutrients</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Summary (Review)</th>
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<tbody>
<tr>
<td><em>This summary may be altered to include real cuts of meat instead of powerpoint slides if the teacher would prefer. Using real meat cuts would allow students to dissect the meat and better experience its texture. If this method of summary is preferred, make sure that all students thoroughly wash their hands and all surfaces after contact with raw meat.</em> Using the last seven slides of the powerpoint, have students individually consider the characteristics of the meat shown and the expected characteristics of the same meat that was produced through a culture. Have students decide whether they would prefer to eat the traditionally grown meat or the cultured meat based strictly on the characteristics of the meat. Ask students for their decisions and their justifications for their views. <strong>Note – As discussion continues, try to encourage students to see both sides of the argument. For example, if they consistently say that traditional meat would be better, ask them about the convenience of having boneless fish fillets or if they would prefer chicken legs without the skin.</strong></td>
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<tr>
<td><strong>Guiding questions – Why would you prefer to eat that type of meat over the other? What characteristics do you think would be different between the two?</strong></td>
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<tr>
<td>Evaluation</td>
<td></td>
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<td>------------------</td>
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<tr>
<td>Students will be evaluated through class discussion.</td>
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<table>
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<th>Items Students Turn In</th>
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<tr>
<td>None.</td>
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</table>
Favorable Meat Characteristics

Instructions: Fill out the guide below to make predictions on the characteristics of traditional meat that would be difficult to produce in cultured meat.

<table>
<thead>
<tr>
<th>Meat Characteristics</th>
<th>Notes about Characteristic</th>
<th>Prediction - difficult to reproduce in cultured meat or not?</th>
<th>Reasons for your prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef:</td>
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<tr>
<td>Carcass Maturity</td>
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<tr>
<td>Texture</td>
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<tr>
<td>Color of Lean</td>
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<tr>
<td>Marbling</td>
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<tr>
<td>Pork:</td>
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<tr>
<td>Color</td>
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<tr>
<td>Marbling</td>
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<tr>
<td>Water-holding capacity</td>
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<tr>
<td>Ultimate pH</td>
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<tr>
<td>Stress Reduction</td>
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<td>Poultry:</td>
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<tr>
<td>Fleshing</td>
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<td>Fat covering</td>
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<tr>
<td>Defects from Handling</td>
<td></td>
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</tr>
</tbody>
</table>
Indicators:
- Carcass maturity – physiological age of animal (not actual age)
- Texture – coarser = older
- Color of lean – darker red = older
- Amount/distribution of marbling – dispersion of fat within the lean meat

Why Beef Quality Assurance?
- Beef Quality Assurance – nationally coordinated, state implemented program
- Provides information to beef producers and consumers of how animal production practices and scientific knowledge can improve beef quality

What is Pork Quality Assurance?
- Pork Quality Assurance – produces education and certification program to improve pork quality
- Altered to PQA Plus in 2007 to reflect consumer interest in the way food animals are raised

Quality Indicators:
- Color – darker pink is preferable
- Marbling – want 2-4% to give appropriate pork flavor
- Water holding capacity – amount of moisture in pork that is lost when it is cut. Lower loss is preferable; should not be higher than 2.5%
- Ultimate pH – acidity of pork 24 hours after slaughter. Predictor of moisture holding capacity; higher pH = better water holding capacity and better pork.
Quality Indicators for Ready-to-Cook Poultry

- Conformation – free of deformities
- Fleshing – well developed meat (breast, leg, drumstick, thigh, wing)
- Fat covering – well-developed, evenly distributed
- Defeathering – no feathers or hairs left on bird
- Exposed flesh – minimal flesh exposed from cuts, tears, and missing skin
- Disjointed and broken bones, missing parts – none present
- Discolorations – minimal. Large discolorations indicate the chicken was not appropriately bled out, bruising, or blood clots
- Freezing defects – minimal
- Backs – meat in appropriate places

Additional quality indicators for specific poultry food products (roasts, breasts, drumsticks, thighs, legs)

Pork quality can be lowered by stress. Short term stress before slaughter = pale, soft pork with decreased moisture holding capacity. Long term stress = dark, firm, dry pork.

Agricultural Marketing Service Poultry Programs maintains US standards
- Quality A, B, C
- “In order for poultry to be eligible for an official USDA grade designation, each carcass or part must be first inspected for wholesomeness by USDA’s Food Safety and Inspection Service (FSIS) and individually graded by a plant grader. Then a sample of the product is taken by a USDA grader. Officially graded poultry that passes this examination and evaluation process…may be graded as A, B, or C.”
Introduction (Interest Approach)

Estimated Time: 10 minutes

Ask students what breed of cattle is promoted by restaurants.  Note – The majority of fast food restaurant commercials promote Angus burgers.  Show students the Angus Cow video (http://www.youtube.com/watch?v=k_CVQYCsuvM).  Ask them if they think cultured meat production is as dependent on selection of certain breeds as traditionally grown meat.

Guiding questions – Why do you think Angus cattle are so highly regarded?  What characteristics of this breed do you think make it a good breed for meat production?  Do you think cultured meat products would be different based on the breed their cells are biopsied from?  Do you think cultured meat production should consider the breed of animal or the animal’s genetics when collecting biopsies?

Daily Plan

Lesson Title: Animal Breeds and Characteristics
Unit Title: Animal Industry
Course: Agriscience Foundations
Estimated Time: 45 minutes

Materials, Supplies, Equipment, References, and Other Resources:
Angus Cow video (http://www.youtube.com/watch?v=k_CVQYCsuvM) Note – this video is also available on dropbox.
Animal Breed and Characteristics Packets (one of each - Beef and Swine - per student)
Breeds and Characteristics Powerpoint

Agriscience Foundations Standards:
6.03 – Illustrate correct terminologies for animal species and conditions within those species.
6.02 – Categorize animals according to use, type, breed, and scientific classification.
6.04 – Compare the basic internal and external anatomy of animals.

Essential Question:
How would traditionally harvested meat compare to cultured meat in its production?

Daily Objectives
1. Identify breeds of animals chosen for specific characteristics related to meat production.
2. Describe the favorable and unfavorable anatomical characteristics of various animals related to meat production.
3. Evaluate the suitability of various breeds of animals for use in cultured meat production.
### Learning Activity 1

**Estimated Time: 15 minutes**

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Brief Content Outline</th>
</tr>
</thead>
</table>
| Arrange students into groups of 2-3. Give each student a copy of both Animal Breeds and Characteristics packets (Beef and Swine). Each group should also receive tape. Students will cut out each of the characteristics. Have students attempt to pair up the name of the breed with the breed characteristics by placing them in the appropriate spots on the paper. When groups have finished, go over this with them to ensure that all students have the correct characteristics with each of the names. Note – Students can be instructed to fold over the third section of the worksheet to keep them from working ahead of the teacher would prefer. It will be used during the class summary. | Beef breeds and their characteristics –
1. Texas Longhorn
2. Brahman
3. Charolais
4. Chianina
5. Limousin
6. Maria-Anjou
7. Simmental
Swine Breeds and their characteristics –
1. Berkshire
2. Chester White
3. Duroc
4. Hampshire
5. Landrace
6. Poland China
7. Spotted Swine
8. Yorkshire
9. Pietrain |

### Learning Activity 2

**Estimated Time: 10 minutes**

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Brief Content Outline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using the Breeds and Characteristics Powerpoint, have students guess each of the breeds shown in the pictures according to the characteristics on their papers.</td>
<td></td>
</tr>
<tr>
<td>Summary (Review)</td>
<td>Estimated Time: 10 minutes</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>Ask students to individually select the top three breeds they would use in the production of cultured meat for each species, and three breeds they would not use. They should complete the appropriate section of the Animal Breeds and Characteristics sheets during this activity. After 6-7 minutes, ask students about their selections and reasons for their selections. <em>Note – the worksheets can be collected and later returned if the teacher would like.</em></td>
<td></td>
</tr>
</tbody>
</table>

**Evaluation**

Students will be evaluated on their worksheets and through discussion.

**Items Students Turn In**

Animal Breeds and Characteristics sheets (optional)
# Animal Breeds and Characteristics

## Beef

<table>
<thead>
<tr>
<th>Breed</th>
<th>Characteristics</th>
<th>Rating for use in cultured meat production and Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charolais</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hereford</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chianina</td>
<td></td>
<td></td>
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<tr>
<td>Angus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Texas Longhorn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limousin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simmental</td>
<td></td>
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</tr>
<tr>
<td>Brahman</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maria-Anjou</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shorthorn</td>
<td></td>
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</tr>
</tbody>
</table>
## Animal Breeds and Characteristics
### Swine

<table>
<thead>
<tr>
<th>Breed</th>
<th>Characteristics</th>
<th>Rating for use in cultured meat production and Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landrace</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yorkshire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chester White</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spotted Swine</td>
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<tr>
<td>Hampshire</td>
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<tr>
<td>Berkshire</td>
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<tr>
<td>Pietrain</td>
<td></td>
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<tr>
<td>Poland China</td>
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<td></td>
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<tr>
<td>Duroc</td>
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</tbody>
</table>
Beef Breed Characteristics – cut these out and tape next to the appropriate breed.

a. only beef breed available to US cattle producers until mid 1800s.
b. Hardy
c. Lacked beefy appearance
d. Difficult to fatten (lean carcasses)
a. Compared to longhorn – increased growth rate,
   improved mothering ability, shorter horns
b. Bred with longhorns to give heavier muscled carcass
c. Beefy appearance
d. Very hardy, able to tolerate wide range of environmental conditions
e. Polled Herefords are naturally hornless
f. Most popular breed of beef cattle
g. Naturally polled
h. Good for hot climates because loose hide dissipates heat well
i. More tolerant to disease than other breeds of cattle
j. Have been used to create other breeds – Brangus, Beefmaster,
   Santa Gertrudis (hardy, good maternal abilities in these three breeds)
k. Rapid growth rate and muscling
l. Used to sire large calves that lead to difficult births,
   but selective breeding for low birth weight solved this problem
m. Largest breed of beef cattle
n. Good growth rate
o. Lean carcasses
p. Moderately framed
q. Heavily muscled
r. Rapid growth rates
s. Great for crossbreeding with large-framed or light-muscled cows
t. Good maternal abilities
u. Docile temperament
v. Largest and heaviest framed of the French breeds
w. Large
x. Heavily muscled
y. Good breeding versatility
Swine Characteristics – cut these out and tape next to the appropriate breed.

a. Used to have short noses, but breeders have selectively bred for long noses to help animals eat from automatic self-feeders
b. Good mothering ability
c. Exceptional muscle quality (color, texture, flavor)
d. Can be used as maternal or paternal for crossbreeding
e. Great mothering ability
f. Good growth rate
g. Good carcass traits
h. Breeders have selected for extreme leanness and muscling to be used as a paternal breed
i. Used as maternal and paternal
j. Good muscling and leanness
k. Large litters
l. Exceptional milking ability
m. Good growth rate
n. Good muscling
o. Hardy
p. Used as paternal breed
q. Farrow and wean large, heavy litters
r. Used as maternal breed
s. Very lean
t. Heavily muscled
u. Many carry two copies of stress gene
v. Used to cross with other paternal breeds to produce lean, heavily muscled, crossbred sires with 0 or 1 copy of the stress gene
BEEF AND SWINE BREEDS
Can you guess which is which by their characteristics?

Slide 1

Texas Longhorn

Shorthorn

Angus

Brahman

Hereford
<table>
<thead>
<tr>
<th>Daily Plan</th>
<th>Socio-Scientific Issues Instruction – Day - 32</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lesson Title:</strong></td>
<td>Cell Differentiation</td>
</tr>
<tr>
<td><strong>Unit Title:</strong></td>
<td>Animal Industry</td>
</tr>
<tr>
<td><strong>Course:</strong></td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>45 minutes</td>
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</tbody>
</table>

**Materials, Supplies, Equipment, References, and Other Resources:**
- Guided Predictions powerpoint
- Computer hooked to projector with internet access

**Agriscience Foundations Standards:**
- 6.04 – Compare the basic internal and external anatomy of animals.
- 3.03 – Identify the parts and functions of plant and animal cells.
- 3.07 – Investigate DNA and genetics applications in agriscience including the theory of probability.

**Essential Question:**
How would traditionally harvested meat compare to cultured meat in its production?

**Daily Objectives**
1. Identify the components of animal cells.
2. Explain the characteristics of traditionally-harvested meat and cultured meat at the cellular level.

**Introduction (Interest Approach)**
- Estimated Time: 5 minutes

Show students the first two photographs on the powerpoint. Hold a brief class discussion about how these items are created. *Note – The teacher should guide the discussion toward cell differentiation. Guiding questions are designed to lead discussion toward this.*

*Guiding questions – How are each of these similar? How do you think they are created? How are they similar to cultured meat production?*
### Learning Activity 1

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Estimated Time: 25 minutes</th>
</tr>
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<tbody>
<tr>
<td>Ask students what would happen if the cultured meat biopsy was taken from a cell that wasn’t a muscle cell. Through the Guided Predictions powerpoint, have the class openly discuss each statement, and then the correct answer. Correct statements should be written in student notes. Then have students re-address the original question – what would happen if the biopsy was taken from a cell that wasn’t a muscle cell? <em>Note – discussion can stem from the related content in the unit plan.</em></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
</tbody>
</table>
| **Guiding questions** – *Do you think that statement is true or false? Why do you think that? So does that change your answer to the original question?* | **1.** Animal cells – all cells originate from other cells. All organisms are made up of one or more cells. All cells have similar functions:  
   a. All cells must take up nutrients from external environment  
   b. All cells must excrete waste products into their external environment  
   c. All cells do some kind of work (make proteins, store energy, carry oxygen, transport electrical impulse, store minerals, move)  
   d. All cells must reproduce  

2. Cell differentiation  
   a. Cells are specialized, and each type of cell has a different job  
      i. Muscle cells – support body and movement  
      ii. Bone cells – structure and support of body  
      iii. Red blood cells – carry oxygen  
      iv. Fat cells – store energy, don’t carry oxygen  
      v. Some make up tissues and organs  
   b. Differentiated cells work together in systems  
      i. Skeletal system  
      ii. Muscular system  
      iii. respiratory system  
      iv. circulatory system  
      v. nervous system  
      vi. endocrine system  
      vii. reproductive system  

Cultured Meat Cells  
   1. All muscle cells  
   2. No attached systems working together |
<table>
<thead>
<tr>
<th>Learning Activity 2</th>
<th>Estimated Time: 5 minutes</th>
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</thead>
<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>Using the next pictures on the Guided Predictions powerpoint (Cell Differentiation), have students identify similarities and differences of the types of cells. Point out that each cell has similar organelles which help it carry out its specific functions.</td>
<td>1. Cell differentiation</td>
</tr>
<tr>
<td><strong>Guiding questions</strong> - If all cells have similar organelles, why are muscle cells needed to grow cultured meat? Do you think cultured meat production could incorporate cell differentiation in order to make more realistic meat products? How?</td>
<td>a. Cells are specialized, and each type of cell has a different job</td>
</tr>
<tr>
<td></td>
<td>i. Muscle cells – support body and movement</td>
</tr>
<tr>
<td></td>
<td>ii. Bone cells – structure and support of body</td>
</tr>
<tr>
<td></td>
<td>iii. Red blood cells – carry oxygen</td>
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<td></td>
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<td></td>
<td>v. Some make up tissues and organs</td>
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<td></td>
<td>b. Differentiated cells work together in systems</td>
</tr>
<tr>
<td></td>
<td>i. Skeletal system</td>
</tr>
<tr>
<td></td>
<td>ii. Muscular system</td>
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<tr>
<td></td>
<td>iii. Respiratory system</td>
</tr>
<tr>
<td></td>
<td>iv. Circulatory system</td>
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<tr>
<td></td>
<td>v. Nervous system</td>
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<tr>
<td></td>
<td>vi. Endocrine system</td>
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<tr>
<td></td>
<td>vii. Reproductive system</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Summary (Review)</th>
<th>Estimated Time: 10 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explain to students that they will be learning about the organelles of animal cells during the next class. They will be comparing cells to other working systems, like in the example they are about to see. Show students the “prezi” located at <a href="http://prezi.com/mrfde7ibr-1a/copy-of-cell-analogy-project/">http://prezi.com/mrfde7ibr-1a/copy-of-cell-analogy-project/</a>. Note – this prezi is also located on Dropbox. Click the prezi folder, open with WinRAR.exe, close the popup screen about buying, open the copy-of-cell… folder, click on prezi.exe. To move through the prezi, click on the right arrow.</td>
<td></td>
</tr>
<tr>
<td><strong>Guiding questions</strong> – So knowing what you do about Spongebob, what do you think this organelle’s job is? What do you think it is responsible for?</td>
<td></td>
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<tr>
<td><strong>Evaluation</strong></td>
<td></td>
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<tr>
<td>Students will be evaluated through their discussion.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Items Students Turn In</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>None.</td>
</tr>
</tbody>
</table>
Cells
And how they function

Guided Predictions
Are each of the following statements true or false?

Lab Grown Bladder

True or False?
• All cells originate from other cells.
• Most organisms are made up of one or more cells.
• All cells must take up nutrients from external environment.
• Cells do not excrete products into their external environment.
• All cells do some kind of work (make proteins, store energy, carry oxygen, transport electrical impulse, store minerals, move).
• Only sex cells reproduce.

True!
False!
True!
False!
True!
False!

Ear frame growing cartilage cells for wounded soldiers

What about each of these?
• Cells differentiate to produce different organs.
• All cells have similar jobs.
• Differentiated cells work together.
• Cultured meat is made of many types of differentiated cells.
• Cultured meat does not have attached systems working together as in an animal’s body.
<table>
<thead>
<tr>
<th>Daily Plan</th>
<th>Socio-Scientific Issues Instruction – Day - 33</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lesson Title:</strong></td>
<td>Cell Anatomy</td>
</tr>
<tr>
<td><strong>Unit Title:</strong></td>
<td>Animal Industry</td>
</tr>
<tr>
<td><strong>Course:</strong></td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>45 minutes</td>
</tr>
</tbody>
</table>

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

A Cell is Like A… sheet (classroom set)
Classroom set of computers with internet access

**Agriscience Foundations Standards:**

3.03 – Identify the parts and functions of plant and animal cells.

**Essential Question:**

How would traditionally harvested meat compare to cultured meat in its production?

**Daily Objectives**

1. Compare and contrast cells and other systems.
2. Explain the functions of different cell organelles.

**Introduction (Interest Approach)**

Estimated Time: 5 minutes

Give students three minutes to consider what they think a cell is like (remind them of the Spongebob prezi from the previous class). Then, go around the room and have each student complete the sentence. Example: A cell is like a house. A cell is like a party. A cell is like a truck.

**Learning Activity 1**

Estimated Time: 30 minutes

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Brief Content Outline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Give each student a computer and a copy of the “A Cell”</td>
<td>1. Animal cell organelles</td>
</tr>
</tbody>
</table>
is Like A…” sheet. Have them go to “Inside a Cell” (http://learn.genetics.utah.edu/content/begin/cells/insideacell/). Tell students that they should go through the cell to identify organelles that are similar to components of something else that they can relate to a cell. Note – an example would be that a cell is like a house. The mitochondria is the heater, the family that lives there is the nucleus, the walls are the cell membrane, etc. Students should be told that they can make the cell membrane transparent or keep it opaque, but they should leave the cell as an animal cell. Worksheet collection is at the discretion of the teacher.

| c. Chromosomes   | d. Cytoplasm  |
| e. Endoplasmic reticulum | f. Mitochondria  |
| g. Lysosomes   | h. Golgi bodies  |

**Summary (Review)**

Estimated Time: 10 minutes

Have several students share their “A Cell is Like A…” comparisons. Student and teacher discussion should focus on how the student made these analogies.

*Guiding questions – Why do you think the cell is like that item? What would the _____ be in the cell? What similarities do you see between this organelle and that item? What actions of that organelle make you think it’s like that item?*

**Evaluation**

Students will be evaluated on their worksheets and discussions.

**Items Students Turn In**

A Cell is Like A… (optional)
### Daily Plan

<table>
<thead>
<tr>
<th>Lesson Title:</th>
<th>Cellular Reproduction - Mitosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Title:</td>
<td>Animal Industry</td>
</tr>
<tr>
<td>Course:</td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>45 minutes</td>
</tr>
</tbody>
</table>

#### Materials, Supplies, Equipment, References, and Other Resources:
- Video ([http://www.youtube.com/watch?v=xwl6oK9gcBE&feature=related](http://www.youtube.com/watch?v=xwl6oK9gcBE&feature=related)) *Note – this video is also located on the dropbox.*
- Mitosis worksheet (classroom set)
- Mitosis powerpoint
- Mitosis signs (one set)
- Computer hooked to projector with internet access

#### Agriscience Foundations Standards:
- 3.03 – Identify the parts and functions of plant and animal cells.
- 3.04 – Describe the phases of cell reproduction.

#### Essential Question:
How would traditionally harvested meat compare to cultured meat in its production?

#### Daily Objectives
1. Explain the process of mitosis.
2. Predict characteristics of cultured meat resulting from mitosis.
### Introduction (Interest Approach)

**Estimated Time: 5 minutes**

Have students watch the video ([http://www.youtube.com/watch?v=xwl6oK9gcBE&feature=related](http://www.youtube.com/watch?v=xwl6oK9gcBE&feature=related)). *Note – this video is also located on the dropbox.* Ask students, “what do we know already about how cultured meat is produced?” This should be a review from previous content, where students learned about the process of lab grown meat production. Ask probing questions related to the actual process of cellular replication.

*Guiding questions – We say that the cells multiply, but how do they do this? Do cells multiply naturally? When they multiply, what is the result? Can they multiply an unlimited number of times? Do you think there are any negative outcomes of cellular multiplication?*

### Learning Activity 1

**Estimated Time: 20 minutes**

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Brief Content Outline</th>
</tr>
</thead>
</table>
| Give each student the Mitosis worksheet. Have students fill out the worksheet while following along the lecture. The first side should be totally completed at the end of the lecture. The students should then work to answer the second side questions. Teacher lecture will be guided by the Mitosis powerpoint. *Note – the teacher can also use the content provided in the unit content guide.* | 1. Interphase – cellular growth
   a. G1
   b. S
   c. G2
   2. Mitosis – division of body cells (nonsex)
   a. Prophase
   b. Metaphase
   c. Anaphase
   d. Telophase |
<table>
<thead>
<tr>
<th>Learning Activity 2</th>
<th>Estimated Time: 15 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>In this activity, students will be acting out the stages of mitosis. Assign the following roles to students by taping the attached Mitosis signs to their shirts: Chromosome A (for hair texture) (2 students – to be sister chromatids) Chromosome B (for hair color) (2 students – to be sister chromatids) Nuclear membrane (three students) Cell membrane (six to eight students) Organelles (2 students) Cytoplasm (2 students) Spindle fibers (2 students) After students are assigned to their parts, explain to students not assigned a part that they will be assisting in the placement of the parts during the stages of mitosis. Students are to organize themselves to represent the appropriate stage as called out (in order from the three subphases of interphase through telophase) by the teacher. When the students think they have the correct action represented, the teacher should check and ask questions to make sure all students are aware of what is going on in the stage. Example – Students should begin according to the diagram on the right. When the teacher calls out Interphase – G1, a second student representing Students assigned a part to be used later (sister chromatids, spindle fibers, etc.)</td>
<td></td>
</tr>
</tbody>
</table>

![Diagram of mitosis stages with student characters]
<table>
<thead>
<tr>
<th>Summary (Review)</th>
<th>Estimated Time: 0 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>If time allows, show students a real cell going through the stages of mitosis</td>
<td></td>
</tr>
<tr>
<td>(<a href="http://www.phschool.com/science/biology_place/labbench/lab3/mitfilm.html">http://www.phschool.com/science/biology_place/labbench/lab3/mitfilm.html</a>).</td>
<td>Pause the video at each</td>
</tr>
<tr>
<td>Pause the video at each stage and ask students to identify which stage it is</td>
<td>stage and ask students to</td>
</tr>
<tr>
<td>and how they know.</td>
<td>identify which stage it is</td>
</tr>
<tr>
<td></td>
<td>and how they know.</td>
</tr>
</tbody>
</table>

**Evaluation**

Students will be evaluated through their discussion and actions during the activity.

**Items Students Turn In**

None.
Mitosis Phases

**Interphase** N

Chromosomes replicate

**Prophase**

Chromosomes line up at equatorial plate

**Metaphase**

Spindle fibers pulling sister toward poles

**Anaphase**

Furrow forms, cytoplasm splits

**Telophase/Cytokinesis**

Cleavage

**Daughter Cells** N

Cells no longer have replicated chromosomes. Cells have pairs.
Mitosis Questions

Is the parent cell haploid or diploid? What does this mean?

What about the daughter cells?

Mitosis results in how many daughter cells?

During which phase of mitosis do chromosomes align their centromeres along the equatorial plate?

Do homologous chromosomes line up next to each other or apart from each other?

What is the difference between homologous chromosomes and replicated chromosomes?

Do daughter cells still have homologous pairs?

Do daughter cells have replicated chromosomes?

How many times does DNA replicate during one cycle of mitosis?

Name each of the phases of mitosis, and draw out what happens in each:
Chromosome A – Wavy Hair
Chromosome A – Wavy Hair
Chromosome B – Brown Hair
Chromosome B – Brown Hair
Nuclear Membrane
Nuclear Membrane
Nuclear Membrane
Cell Membrane
Cell Membrane
Cell Membrane
Cell Membrane
Cell Membrane
Cell Membrane
A Cell is Like A…

Name _________________________

A cell is like a __________________________.

<table>
<thead>
<tr>
<th>The</th>
<th>is like the cell membrane</th>
<th>because</th>
</tr>
</thead>
<tbody>
<tr>
<td>The</td>
<td>is like the nucleus</td>
<td>because</td>
</tr>
<tr>
<td>The</td>
<td>are like the chromosomes</td>
<td>because</td>
</tr>
<tr>
<td>The</td>
<td>is like the endoplasmic reticulum</td>
<td>because</td>
</tr>
<tr>
<td>The</td>
<td>is like the mitochondria</td>
<td>because</td>
</tr>
<tr>
<td>The</td>
<td>are like the lysosomes</td>
<td>because</td>
</tr>
<tr>
<td>The</td>
<td>are like the golgi bodies</td>
<td>because</td>
</tr>
<tr>
<td>The</td>
<td>is like the cytoplasm</td>
<td>because</td>
</tr>
</tbody>
</table>

On the back of this sheet, draw your analogy to display how items in your example are related to the cell parts above.
Introduction (Interest Approach)

Ask students to consider themselves cultured meat scientists for a minute. As cultured meat scientists, how would they go about selecting the perfect animal from which to take a biopsy?

Guiding questions – Why would it be important to choose an ideal animal? (remember that mitosis produces identical cells) What characteristics would you want to see in the animal whose muscle cells you will use? How does this differ from traditional meat production?
Show students the beef selection video ([http://www.pbs.org/wnet/nature/lessons/the-perfect-cow/video-segments/1536/](http://www.pbs.org/wnet/nature/lessons/the-perfect-cow/video-segments/1536/)). You can turn the video off at the beginning of the dairy cow discussion. Explain to students that while cultured meat production is done strictly through mitosis, traditional meat production uses both production of muscle cells through mitosis (during animal growth) and selection of traits of parents to produce favorable offspring to produce that muscle. Explain to students that over the next few days, you will be examining how traditional meat production uses cellular reproduction in ways different than lab grown meat.

<table>
<thead>
<tr>
<th>Learning Activity 1</th>
<th>Estimated Time: 20 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
</tbody>
</table>
| Give students the meiosis worksheet. Students should complete the worksheet as the teacher lectures using the meiosis powerpoint. | 1. Meiosis – division of sex cells  
   a. Meiosis I  
   b. Meiosis II |

<table>
<thead>
<tr>
<th>Summary (Review)</th>
<th>Estimated Time: 15 minutes</th>
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</thead>
<tbody>
<tr>
<td>Put students into pairs. Give each pair a meiosis flip book sheet (5 pages). Students can share pairs of scissors. Have students work in partners to draw in chromosomes and add captions to each page of the flip book, then assemble flip books using a stapler. Turning these in is at the discretion of the teacher, but they should be returned to the student for review.</td>
<td></td>
</tr>
</tbody>
</table>

**Evaluation**

Students will be evaluated through discussion and through flip books

**Items Students Turn In**

Meiosis flip books (optional)
Meiosis

- Division of sex cells
  - Sperm – spermatogenesis
    - One sex cell results in four sperm that are all genetically different
  - Ova – oogenesis
    - One sex cell results in one egg and three polar bodies that get reabsorbed into the body

What happens during meiosis, anyway?

- What differences or similarities did you see between meiosis and mitosis?
- Let’s look at that a bit slower...

2N becomes 1N

All together now!
What happens during meiosis, anyway?

Watch again – this time, describe what is happening during each stage.
<table>
<thead>
<tr>
<th>Daily Plan</th>
<th>Socio-Scientific Issues Instruction – Day 36</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lesson Title:</strong></td>
<td>Products of Meiosis and Mitosis</td>
</tr>
<tr>
<td><strong>Unit Title:</strong></td>
<td>Animal Industry</td>
</tr>
<tr>
<td><strong>Course:</strong></td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>45 minutes</td>
</tr>
<tr>
<td><strong>Materials, Supplies, Equipment, References, and Other Resources:</strong></td>
<td>Venn Diagram Set (one per group of three students)</td>
</tr>
</tbody>
</table>

**Agriscience Foundations Standards:**
- 3.03 – Identify the parts and functions of plant and animal cells.
- 3.04 – Describe the phases of cell reproduction.
- 3.07 – Investigate DNA and genetics applications in agriscience including the theory of probability.

**Essential Question:**
How would traditionally harvested meat compare to cultured meat in its production?

**Daily Objectives**
1. Compare and contrast the processes of mitosis and meiosis.
2. Compare and contrast the products of mitosis and meiosis in meat production.

**Introduction (Interest Approach)**
<table>
<thead>
<tr>
<th>Estimated Time: 10 minutes</th>
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</thead>
<tbody>
<tr>
<td>Ask students to think-pair-share the following two questions:</td>
</tr>
<tr>
<td>- How is meiosis used in lab grown meat production and traditional meat production?</td>
</tr>
<tr>
<td>- How is mitosis used in lab grown meat production and traditional meat production?</td>
</tr>
<tr>
<td>During the sharing, the teacher should identify student misconceptions (for example, if a student thinks meiosis is used in lab grown meat production).</td>
</tr>
</tbody>
</table>
Learning Activity 1  
Estimated Time: 25 minutes

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Brief Content Outline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explain to students that because mitosis and meiosis are very similar, but are actually two distinct processes, they will be comparing the two today. Arrange students in groups of three. Each group will receive a set of Venn Diagrams.</td>
<td></td>
</tr>
<tr>
<td>Have each student complete one of the venn diagrams based on their notes from the previous classes. <em>Note – the venn diagram for characteristics of meiosis and mitosis does not include a comparison of their stages. This diagram should focus more on haploid vs. diploid, number of chromosomes, types of cells, etc.</em></td>
<td></td>
</tr>
<tr>
<td>When each student in the group is finished, have the students share their diagrams with one another to determine if anything needs to be added based on other group members’ opinions and knowledge, and to evaluate whether the material included is correct.</td>
<td></td>
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</tbody>
</table>

Summary (Review)  
Estimated Time: 10 minutes

<p>| | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Have selected members from each group share their venn diagrams. Go over each with the class by diagram, asking students to contribute their thoughts to each specific diagram. Turning in the diagrams at the end of class is at the discretion of the teacher.</td>
<td></td>
</tr>
<tr>
<td><em>Guiding questions</em> – <em>Do you think that what student A said is correct? Would you add anything else to that diagram? What else do you think is similar? What else do you think is different?</em></td>
<td></td>
</tr>
</tbody>
</table>

Evaluation

Students will be evaluated through their diagrams and their discussion.

Items Students Turn In

Venn diagrams (optional)
Use the diagram above to compare how mitosis and meiosis are used in lab grown meat production and traditional meat production.
Use the diagram above to compare how mitosis and meiosis are used in lab grown meat production and traditional meat production.
Use the diagram above to compare the process and stages of mitosis and meiosis
Meiosis

1st cell division of meiosis

paternal homologue
maternal homologue

__ N

over

2nd cell division of meiosis

Sister
still
present

2 daughter cells

Anaphase 2

4 daughter
cells

Telophase 2

Prophase 1
Metaphase 1
Anaphase 1
Telophase 1
Prophase 2
Metaphase 2
Meiosis Questions

How many cells results from meiosis?

Are parent cells haploid or diploid?

How about daughter cells?

What is crossing over, and when does it occur?

How does crossing over impact genetic diversity?

What is a chiasmata?

How are the chromosomes that line up during metaphase I differ from those that line up during mitosis?

How many times does DNA replicate during meiosis?

How many divisions are there in meiosis?

How is this different than in mitosis?

What are tetrads? Are they formed in mitosis?

During mitosis, are the genes of the daughter cells identical or different? What about during meiosis?

Why is meiosis important to traditional meat production?
### Daily Plan

<table>
<thead>
<tr>
<th>Lesson Title:</th>
<th>Industry Predictions from Production Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Title:</td>
<td>Introduction of Cultured Meat</td>
</tr>
<tr>
<td>Course:</td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>45 minutes</td>
</tr>
</tbody>
</table>

### Socio-Scientific Issues Instruction – Day 37

**Materials, Supplies, Equipment, References, and Other Resources:**
- Posterboards (or large sheets of blank paper, or 2-4 sheets of computer paper taped together) (classroom set)
- Markers, crayons, colored pencils, etc.
- Industry Predictions Guide Sheet (classroom set – each page contains three sheets)
- Industry Reflections Sheet (classroom set)

**Agriscience Foundations Standards:**
- 3.08 – Evaluate advances in biotechnology that impact agriculture (e.g. transgenic crops, biological controls, etc.)
- 9.03 – Identify and demonstrate ways to be an active citizen.
- 9.05 – Demonstrate the ability to work cooperatively.

**Essential Question:**
How would the incorporation of cultured meat into the nation’s food supply impact consumers, the agricultural industry, the environment, and the economy?

**Daily Objectives**
1. Evaluate differences between the meat industries of traditional and cultured meat caused by differences in cellular reproduction needed.
2. Analyze potential problems in the cellular reproduction processes required by traditionally and lab grown meat.

### Introduction (Interest Approach)

**Estimated Time: 5 minutes**

Ask students how they think a farm to mass produce ground beef and a farm to mass produce cultured ground beef would differ. Hold a brief class discussion.
Guiding questions – How would the facilities be different? What about incoming products? How many and what types of animals would the farm have? How is this linked to their processes of cellular reproduction? How much land would be needed? What types of workers would be needed?

<table>
<thead>
<tr>
<th>Learning Activity 1</th>
<th>Estimated Time: 15 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>Arrange students in pairs. Each pair of students will draw two farms that represent the industry created through each respective production method. One student will draw a farm representative of lab grown meat production and the other will draw a farm representative of traditionally grown meat production. Students should follow the Industry Predictions Guide to include appropriate items in their drawings.</td>
<td></td>
</tr>
<tr>
<td><strong>Note</strong> – during this activity, the teacher should monitor student progress by asking questions about students’ predictions and how they are being represented in their drawings.</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Learning Activity 2</th>
<th>Estimated Time: 10 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>Have selected groups share their posters and discuss the differences they noted in the farms with the class.</td>
<td></td>
</tr>
<tr>
<td><strong>Guiding questions</strong> – What long term impacts do you think that difference would cause? How do you see this impacting the industry in the long term? What do you think the industry could do to reduce long term problems?</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Summary (Review)</th>
<th>Estimated Time: 5 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have each student individually complete the industry reflection sheet and turn it in.</td>
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</tbody>
</table>
## Evaluation

Students will be evaluated on their posters and their reflection sheets.

## Items Students Turn In

Industry Reflection Sheet
Industry Predictions Sheet

Use the following predictions to guide your illustrations of your farm. Remember, your farm should represent all aspects of the industry, not just those typically located on a farm (this includes inputs, wastes, and meat processing among other aspects).

What types of facilities does your farm need? Why are each of these items needed? Be sure to consider all aspects of the meat production process, from inputs to wastes, and items needed to continue production.

What types and how many animals will your farm need? How will these animals be housed?

What types of and how many employees will your farm need?

Industry Reflections Sheet

Name ______________________

Question: Based on what you know about cellular reproduction and how meiosis and mitosis are used in the creation of meat, what are your perceptions of the production of lab grown meat? Support your viewpoint with statements related to cellular reproduction and potential related impacts.
My Meiosis Flipbook

by

Prophase I

Metaphase I
### Daily Plan

<table>
<thead>
<tr>
<th>Lesson Title:</th>
<th>Genetic Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Title:</td>
<td>Animal Industry</td>
</tr>
<tr>
<td>Course:</td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>45 minutes</td>
</tr>
</tbody>
</table>

**Materials, Supplies, Equipment, References, and Other Resources:**
- Genetic Probability Guide (classroom set)
- Genetic Probability powerpoint
- Genetic Probability lab sheet (classroom set)
- Paper plates (one per 2 students)
- Pennies (one per 2 students)
- Students’ animal breeds notes from earlier in the unit

**Agriscience Foundations Standards:**
- 3.07 – Investigate DNA and genetics applications in agriscience including the theory of probability.
- 6.03 – Illustrate correct terminologies for animal species and conditions within those species.
- 6.02 – Categorize animals according to use, type, breed, and scientific classification.
- 6.04 – Compare the basic internal and external anatomy of animals.

**Essential Question:**
How would traditionally harvested meat compare to cultured meat in its production?

**Daily Objectives**
1. Identify components of DNA.
2. Describe the process of genetic probability.
<table>
<thead>
<tr>
<th>Introduction (Interest Approach)</th>
<th>Estimated Time: 5 minutes</th>
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</thead>
<tbody>
<tr>
<td>Show students the first four powerpoint slides. At each one, ask students to identify parent characteristics that were exhibited in the offspring. After the final slide, ask them how producers are able to get characteristics they want out through animal reproduction.</td>
<td></td>
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</tbody>
</table>

*Guiding questions – How are traits passed down from parent to offspring? How can producers use this to their advantage? Do all offspring always contain desired traits? Why or why not?*

<table>
<thead>
<tr>
<th>Learning Activity 1</th>
<th>Estimated Time: 15 minutes</th>
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</thead>
<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>Pass out the Genetic Probability Guide. Have students follow the sheet and record notes as the teacher uses the powerpoint to guide discussion about genetics. <em>Note – the guide should be the main source of discussion. The powerpoint is designed to be used as a supplement to the guide, to help students grasp certain concepts.</em></td>
<td></td>
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</table>

*Guiding questions are included in the student sheet. Teachers should facilitate discussion that elaborates on these questions.*

<table>
<thead>
<tr>
<th>Learning Activity 2</th>
<th>Estimated Time: 10 minutes</th>
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</thead>
<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>Have students get into partners (boy-girl partners is favorable, but not necessary). Give each partner a genetic probability lab sheet and a paper plate. Have students follow the directions on the lab sheet to create a child that is a genetic combination of the two student “parents”. <em>Note – collection of the lab sheet is at the discretion of the teacher.</em></td>
<td></td>
</tr>
<tr>
<td><strong>Summary (Review)</strong></td>
<td><strong>Estimated Time: 5 minutes</strong></td>
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<tr>
<td>Ask students to look at their animal breeds notes from earlier in the unit. Hold a discussion about which characteristics breeds are selected for when selectively breeding for meat production.</td>
<td></td>
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</tbody>
</table>

*Guiding questions – If you were a meat producer, which breeds would you cross? Why? What characteristics are sought out in that breed? Why are these characteristics beneficial?*

<table>
<thead>
<tr>
<th><strong>Evaluation</strong></th>
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</thead>
<tbody>
<tr>
<td>Students will be evaluated on their lab sheets and discussion.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Items Students Turn In</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetic probability lab sheet (optional)</td>
</tr>
</tbody>
</table>
Genetic Probability Guide

We already know that genes are passed down from parents to offspring through meiosis. But how do the genes actually result in certain traits? Can we use our knowledge of genes to select parents to create certain traits in the offspring? This worksheet will serve as your guide to answer these questions.

How do genes make traits?

- Chromosomes
- DNA
- Genes
- Proteins
- Amino Acids
- Nitrogen Bases

Four Nitrogen Bases:

Base Pairs:
Practice:

How are traits passed down?

Genes control:

Alleles:

$$Aa \quad A = \text{nice} \quad a = \text{mean}$$

Which is the dominant allele?
Which is the recessive allele?

How do you know that the phenotype will be when looking at this genotype?

Is the above genotype homozygous or heterozygous?

What would a homozygous genotype look like?

Are there any other homozygous genotypes?

What would the phenotypes be for the two homozygous genotypes?

How would the heterozygous phenotypes be expressed if this were a trait that had incomplete dominance?

How do people have very varied heights or skin colors?

What is a punnett square for?

Draw a punnett square for the following two parents: Aa x Aa

What would the phenotypes be for these offspring?

What do you need to be able to use a punnett square?

Following the powerpoint links, recreate the monohybrid and dihybrid punnett squares below:
Genetic Probability

Can we use our knowledge of genes to produce offspring with desired traits?

Lion + Tiger = Liger

Brahma + Angus = Brangus

Augi = Australian Shepherd + Corgi

Zebra + Donkey = Zedonk

How do genes make traits?
- Chromosomes have DNA
- DNA is made up of genes
- Genes code for specific traits through the creation of certain proteins
- Proteins are made up of amino acids
- Amino acids are made in a certain order according to the genetic code of 4 nitrogen bases
Slide 7
- 4 nitrogen bases (aka nucleotides) are Adenine, Thymine, Guanine, and Cytosine.
- The ladder shape (double helix) of DNA partners up the nitrogen base pairs.
- Bases have to pair up in this fashion:
  - Adenine & Thymine
  - Cytosine & Guanine
- DNA gets replicated using these bases
- Replicated DNA goes into new cell during meiosis

Slide 10
- Three base pairs = codon
- Codon codes for an amino acid
- String of amino acids make up a specific protein
- Proteins make up traits

Slide 8
DNA Double Helix

Slide 11
Genetic Diversity...
- Different arrangements of NUCLEOTIDES in a nucleic acid (DNA) provides the key to DIVERSITY among living organisms.

Slide 9
The Code of Life...
- The "code" of the chromosome is the SPECIFIC ORDER that bases occur.
  ATCGTATGCGG...

Slide 12
Practice...
- Complete the other side of this DNA strand.
So how are these traits passed down?

- Traits are controlled by genes
  - Some are controlled by one gene
  - Some are controlled by more than one gene
- Each gene has two possible alleles
  - Dominant – indicated by capital letter
  - Recessive – indicated by lowercase letter

Aa

Homozygous vs. Heterozygous

- Homozygous = the same
  - AA (leads to dominant phenotype)
  - Aa (leads to recessive phenotype)
- Heterozygous = different
  - Aa
  - Dominant allele always goes first in the combination (leads to dominant phenotype)

Incomplete Dominance

- In some traits, the heterozygous combination leads to a third phenotype that is a mixture of the dominant and recessive.
- Ex:  AA = brown coat
  - aa = white coat
  - Aa = roan coat

Earlobe example:

- A = attached earlobes
- A = free earlobes
- What would these people look like?
  - AA? Attached
  - Aa? Attached
  - aa? Free

Multiple Alleles

- Trait is controlled by more than one gene
  - Hair color
  - Height
  - Eye color
- Results in many different phenotypes, not just 2.
Multiple Allele Example – hair color
- AABB = black
- AABb = black
- AAbb = red
- AaBB = brown
- AaBb = brown
- Aabb = regular blond
- aaBB = dark brown
- aaBb = regular brown
- Aabb = pale yellow blond

A note on inbreeding…
- Crossbreeding – breeding two unrelated individuals
  - Results in hybrid vigor (aka heterosis): the offspring are genetically superior to the parents (cross results in quality/function better than either parent).
- Inbreeding - lack of hybrid vigor. Opposite occurs.

So how can we predict outcomes of breeding?
- Punnett Squares predict likelihood of offspring having certain traits
- Can be used if the genotypes of animals are known
  - Some genotypes can be guessed because the animal displays the dominant trait.
  - Ex – according to the previous slide, what is your genotype for hair color?

How to fill in a Punnett Square
- Monohybrid Cross (for predicting one trait)
- Dihybrid Cross (for predicting two traits)
In this activity, you will design a parent, then create a kid with another parent in the class using the two parents' genotypes to randomly determine how the kid will look. Since each gene has 2 possibilities (alleles), we will use a coin to determine which allele you will give your kid. Heads will be the dominant gene, tails will be the recessive gene. What do you do if you have 2 dominant genes? Or 2 recessive genes? Right, you are guaranteed to give your kid that gene, so there is no need to flip a coin.

These are the characteristics that you will be using:

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Homozygous Dominant</th>
<th>Heterozygous</th>
<th>Homozygous Recessive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jaw Shape</td>
<td>JJ - round</td>
<td>Jj - round</td>
<td>jj - square</td>
</tr>
<tr>
<td>Chin Prominence</td>
<td>VV - very prominent</td>
<td>Vv - very prominent</td>
<td>vv - less prominent</td>
</tr>
<tr>
<td>Chin Shape (only flip coins if chin prominence is VV or Vv)</td>
<td>RR - round</td>
<td>Rr - round</td>
<td>rr - square</td>
</tr>
<tr>
<td>Cleft Chin</td>
<td>AA - absent, no cleft</td>
<td>Aa - absent, no cleft</td>
<td>aa - cleft is present</td>
</tr>
<tr>
<td>Hair Curliness (incomplete dominance)</td>
<td>CC - straight</td>
<td>Cc - wavy</td>
<td>cc - curly</td>
</tr>
<tr>
<td>Characteristic</td>
<td>Homozygous Dominant</td>
<td>Heterozygous</td>
<td>Homozygous Recessive</td>
</tr>
<tr>
<td>----------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>Widow’s peak – the hairline comes to a point in the center of the forehead (even slightly)</td>
<td>WW – present (even a slight one)</td>
<td>Ww – present (even a slight one)</td>
<td>ww – absent, no point</td>
</tr>
<tr>
<td>Eyebrow shape</td>
<td>BB – bushy</td>
<td>Bb – bushy</td>
<td>bb – fine</td>
</tr>
<tr>
<td>Eyebrow spacing</td>
<td>NN – not connected</td>
<td>Nn – not connected</td>
<td>nn – connected</td>
</tr>
<tr>
<td>Eyebrow color</td>
<td>HH – darker than hair color</td>
<td>Hh – same color as hair color</td>
<td>hh – lighter than hair color</td>
</tr>
<tr>
<td>Eyes – Distance Apart</td>
<td>EE – close together</td>
<td>Ee – average distance</td>
<td>ee – far apart</td>
</tr>
<tr>
<td>Eyes – Size</td>
<td>EE – large</td>
<td>Ee – medium</td>
<td>ee – small</td>
</tr>
<tr>
<td>Eyes – Shape</td>
<td>AA – almond, wide</td>
<td>Aa – almond, wide</td>
<td>aa – round, narrow</td>
</tr>
<tr>
<td>Characteristic</td>
<td>Homozygous Dominant</td>
<td>Heterozygous</td>
<td>Homozygous Recessive</td>
</tr>
<tr>
<td>-----------------</td>
<td>------------------------------</td>
<td>------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Eyes – Slant</td>
<td>HH – horizontal (no slant)</td>
<td>Hh – horizontal (no slant)</td>
<td>hh – upward slant</td>
</tr>
<tr>
<td>Eye Color</td>
<td>BBGG – intense brown</td>
<td>BBGb – intense brown</td>
<td>bbbb – light blue</td>
</tr>
<tr>
<td></td>
<td>BbGG – brown with green</td>
<td>BBgb – brown</td>
<td></td>
</tr>
<tr>
<td></td>
<td>flakes</td>
<td>BbGb – brown</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bbbb – brown</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>BbGG – gray blue</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>bbGb – dark blue</td>
<td></td>
</tr>
<tr>
<td>Eyelash Length</td>
<td>LL – long</td>
<td>LL – long</td>
<td>U – short</td>
</tr>
<tr>
<td>Mouth Width</td>
<td>MM – wide</td>
<td>Mm – average</td>
<td>mm – thin</td>
</tr>
<tr>
<td>Lip Thickness</td>
<td>TT – thick</td>
<td>Tt – thick</td>
<td>tt – thin</td>
</tr>
<tr>
<td>Dimples</td>
<td>DD – present</td>
<td>Dd – present</td>
<td>dd – absent</td>
</tr>
<tr>
<td>Nose size</td>
<td>NN – large</td>
<td>Nn – medium</td>
<td>nn – small</td>
</tr>
<tr>
<td>Earlobes</td>
<td>GG – free</td>
<td>Gg – free</td>
<td>gg – attached</td>
</tr>
<tr>
<td>Ear Size</td>
<td>SS – large</td>
<td>Ss – medium</td>
<td>ss – small</td>
</tr>
</tbody>
</table>
**Part 1: Design the Parent**

1. Choose a genotype for each trait. Choose some homozygous dominant traits, some heterozygous traits, and some homozygous recessive traits.
2. Write the correct phenotype for each trait.
3. Then, draw your parent on a blank sheet of paper. Be sure to include the name on the paper.

<table>
<thead>
<tr>
<th>Name of Parent:</th>
<th>Characteristic</th>
<th>Genotype</th>
<th>Phenotype</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jaw Shape</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chin Prominence</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chin Shape (only flip coins if chin prominence is VV or Vv)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cleft Chin</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hair Curliness (incomplete dominance)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Widow's peak</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hair Color</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eyebrows</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eyebrow spacing</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eyebrow color</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eyes- Distance Apart</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eyes – Size</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eyes – Shape</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eyes – Slant</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eye Color</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eyelash Length</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Mouth Width</td>
<td></td>
<td></td>
</tr>
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<td></td>
<td>Lip Thickness</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Dimples</td>
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<td></td>
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<tr>
<td></td>
<td>Nose size</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Earlobes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ear Size</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Part 2: Create-a-kid

1. With your partner, determine what one kid will look like. If you are homozygous for a trait, then write one gene for your contribution to your kid in your column. If you are heterozygous for a trait, flip a coin to see which gene you will give your kid, then write it in your column.

2. Then, draw your kid on the paperplate, using it as a face. Be sure to include the name on your paper.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Genotype</th>
<th>Genotype Description</th>
<th>Phenotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>Names of parents</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jaw Shape</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chin Prominence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chin Shape (only flip coins if chin prominence is W or Vv)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleft Chin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hair Curliness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Widow’s peak</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hair Color</td>
<td></td>
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<td></td>
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<tr>
<td>Eyebrows</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eyebrow spacing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eyebrow color</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eyes- Distance Apart</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eyes – Size</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eyes – Shape</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eyes – Slant</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Eye Color</td>
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<td></td>
<td></td>
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<tr>
<td>Eyelash Length</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mouth Width</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Lip Thickness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimples</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nose size</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Earlobes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ear Size</td>
<td></td>
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</tr>
<tr>
<td>Daily Plan</td>
<td>Socio-Scientific Issues Instruction – Day 39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>---------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lesson Title:</strong></td>
<td>Punnett Squares and Making Selective Breeding</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Unit Title:</strong></td>
<td>Animal Industry</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Course:</strong></td>
<td>Agriscience Foundations</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>45 minutes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| **Materials, Supplies, Equipment, References, and Other Resources:** | Classroom set of computers with internet access  
Classroom computer hooked to a projector and the internet.  
Zoo matchmaker worksheet (classroom set) |
| **Agriscience Foundations Standards:** | 3.07 – Investigate DNA and genetics applications in agriscience including the theory of probability.  
6.03 – Illustrate correct terminologies for animal species and conditions within those species. |
| **Essential Question:** | How would traditionally harvested meat compare to cultured meat in its production? |
| **Daily Objectives** | 1. Apply genetic probability principles to reproduction decisions.  
2. Utilize punnett squares to make predictions regarding genetic probability. |

### Introduction (Interest Approach)  
Estimated Time: 10 minutes

Explain to students that breeding decisions rely heavily on genetics in all areas of animal and plant breeding. On your computer, go to [http://www.mnzoo.org/education/games/matchmaker/index.html](http://www.mnzoo.org/education/games/matchmaker/index.html) and click on “Start Intro”.  
*Note – make sure sound is on so students can hear the introduction.* After the introduction is over, ask students to consider how a breeder might increase disease resistance in a population of animals, like tigers.

**Guiding questions –** *What phenotypes of animals would you want to breed if disease resistance was a recessive trait? Would animals with a phenotype not displaying disease resistance be able to contribute recessive genes for disease resistance to offspring? What might be an added issue to consider if you’re breeding a limited population of animals over several generations?*
<table>
<thead>
<tr>
<th>Learning Activity 1</th>
<th>Estimated Time: 25 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
</tbody>
</table>
| Give each student a computer with internet access. *Note – this activity can be done in pairs as well if an entire classroom set is not available.* Give each student a Zoo Matchmaker worksheet. Have students go to the same website on their computers and click “Skip Intro”. Have all students click on “Maximize Disease Resistance” (on the left). *Note – students MUST read the instructions before they click “Start Breeding”. These instructions are crucial in making breeding decisions during the activity.*  
The directions on the top of the lab sheet should help students with the procedures and shows them how to record tigers’ levels of relatedness, disease resistance, and who they bred at each generation. *Note – as students go through the lab, the teacher should walk the room and ask them questions about how they are making decisions regarding who to breed and what their current level of inbreeding and disease resistance is.* |

<table>
<thead>
<tr>
<th>Summary (Review)</th>
<th>Estimated Time: 10 minutes</th>
</tr>
</thead>
</table>
| When all students have completed the activity and have finished filling in their worksheets, hold a discussion focusing on student reactions to the results of their breeding decisions.  
  
*Guiding questions – How could you tell if an animal was disease resistant? Were you able to keep your disease resistance as low as you expected? Why or why not? How did you make decisions about who to breed? Did you expect that level of inbreeding by the last generation? If you were to do this again, would you choose different partners to breed at any point?* |

**Evaluation**  
Students will be evaluated on their discussion after the Zoo Matchmaker.

**Items Students Turn In**  
Zoo Matchmaker lab sheets (optional)
Zoo Matchmaker Data Tables—Disease Resistance

Use the following tables to keep track of the direct relations of the tigers in each generation.
- Place a 1 in each box for tigers that are first cousins.
- Place a 2 in each box for tigers that are second cousins.
- Place an ‘X’ in each box for tigers that are siblings.
- Place an ‘h’ in each box for tigers that are half-siblings.

Example: In the founding generation (GEN 1), Tevye is a first cousin to Nadia, Tsamara, and Raisa. A “1” has been filled in to each box to indicate this relationship.

Use the same data tables to fill in breeding pairs of tigers. If you breed Katja with Tevye, place an “X” through that box or color it in to show the breeding. This will help you keep track of tigers you have bred so you can avoid inbreeding.

Finally, use the columns/rows marked with a “***” to fill in the genotype (DD, Dd, or dd) of each tiger.

At the end, record the Total Disease Resistance for each generation.

<table>
<thead>
<tr>
<th>GEN 1</th>
<th>Tevye</th>
<th>Adrienne</th>
<th>Markie</th>
<th>Nadia</th>
<th>Tsamara</th>
<th>Raisa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

At end of breeding round:
- Total Disease Resistance
- Total Inbreeding

<table>
<thead>
<tr>
<th>GEN 2</th>
<th>Anastasia</th>
<th>Gaia</th>
<th>Kashka</th>
<th>Inga</th>
<th>Tatiana</th>
<th>Chanda</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

At end of breeding round:
- Total Disease Resistance
- Total Inbreeding

<table>
<thead>
<tr>
<th>GEN 3</th>
<th>Luna</th>
<th>Zara</th>
<th>Malia</th>
<th>Mona</th>
<th>Kali</th>
<th>Katarina</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

At end of breeding round:
- Total Disease Resistance
- Total Inbreeding

<table>
<thead>
<tr>
<th>GEN 4</th>
<th>Sindi</th>
<th>Helga</th>
<th>Sasha</th>
<th>Luna</th>
<th>Natasha</th>
<th>Alexis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>**</td>
<td></td>
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</tr>
</tbody>
</table>

At end of breeding round:
- Total Disease Resistance
- Total Inbreeding
**Daily Plan**

<table>
<thead>
<tr>
<th>Lesson Title:</th>
<th>Maintaining Genetic Diversity through Reproduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Title:</td>
<td>Animal Industry</td>
</tr>
<tr>
<td>Course:</td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>45 minutes</td>
</tr>
</tbody>
</table>

**Materials, Supplies, Equipment, References, and Other Resources:**
- Livestock Reproductive Plan (classroom set)
- Student livestock breed notes from previously in the unit

**Agriscience Foundations Standards:**
- 3.07 – Investigate DNA and genetics applications in agriscience including the theory of probability.
- 6.03 – Illustrate correct terminologies for animal species and conditions within those species.
- 6.02 – Categorize animals according to use, type, breed, and scientific classification.
- 6.04 – Compare the basic internal and external anatomy of animals.

**Essential Question:**
How would traditionally harvested meat compare to cultured meat in its production?

**Daily Objectives**
1. Compare and contrast the benefits and drawbacks of different breeds of cattle with regard to meat production.
2. Create a long term reproductive plan to create lab grown meat while maintaining genetic diversity.

**Introduction (Interest Approach)**
Estimated Time: 10 minutes

Explain to students that the production of cultured meat would potentially need only one superior animal, which could eliminate the need for genetic diversity. Ask students to choose a position regarding the importance of maintaining genetic diversity in cattle if cultured meat was mass produced (students should decide whether breeders should maintain genetic diversity in the future or breed...
the best animal and then just clone it, eliminating genetic diversity). Note – the decision is not related to whether cultured meat should be produced. This situation assumes that cultured meat is already being produced and considers how the livestock industry should move forward.

<table>
<thead>
<tr>
<th>Learning Activity 1</th>
<th>Estimated Time: 25 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>Once each student makes their decision (this does not have to be done aloud), give each student the Livestock Reproductive Plan. Students will complete the plan individually based on their decision above. They should use their livestock breeds notes to help them select breeds. Note – as the students are creating their plans, the teacher should monitor student progress and ask students questions to keep them on track and from getting confused. This task requires a high cognitive level and can lead to student questions and frustration, if those questions go unanswered.</td>
<td></td>
</tr>
<tr>
<td><strong>Guiding questions</strong> – What is the goal of your reproductive plan – maintaining genetic diversity or producing one superior animal? If you are maintaining genetic diversity, why do you feel that is important when cultured meat is in production? Which breeds are you including in your plan? Why? Which genes are you selecting for? Why? Are there genes you are trying to avoid? Why? How successful is your breeding so far?</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Summary (Review)</th>
<th>Estimated Time: 10 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Once students are finished creating their reproductive plans, ask students to reflect on their overall plan. Select students to share the goal of their reproductive plan, the strengths of their plan, the weaknesses of their plan, and their overall reaction to the job responsibilities of a livestock breeder.</td>
<td></td>
</tr>
</tbody>
</table>

**Evaluation**

Students will be evaluated on their plans and their discussion.

**Items Students Turn In**

Livestock Reproductive Plans
Name __________________________________________

Livestock Reproductive Plan

Instructions: You will be producing a livestock reproduction plan for the next three generations based on your overall goal (genetic diversity or ideal animal). Record your goal, and then use the herd below to breed two generations of animals to get as close to your goal as possible. Items in **Bold** require responses from you.

**Goal of Plan:** ________________________________

**Genotypes:**

- **Muscling -**
  - A = heavy muscling
  - A = light muscling

- **Growth Rate -**
  - B = rapid growth
  - b = slow growth

**Your Current Herd:**

- **Angus**
  - Aa
  - Bb

- **Longhorn**
  - aa
  - Bb

- **Charolais**
  - AA
  - Bb

- **Limmousin**
  - AA
  - BB

- **Brahman**
  - aa
  - BB

**Phenotypes:**

- **Angus**
  - Aa
  - Bb

- **Longhorn**
  - aa
  - bb

- **Charolais**
  - AA
  - BB

- **Limmousin**
  - AA
  - BB

- **Simmental**
  - Aa
  - Bb
Reproduction Plan:

Breed: _______ _______

Genotypes: _______ _______

Punnett Square:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</table>

Your above partners have two offspring – one bull and one heifer. Choose two potential offspring from the punnett square and breed each with another animal from your herd. (Note – you can choose more desirable combinations from the punnett square.)
Each of the above pairs has two offspring – each with one bull and one heifer. Choose two potential offspring from the punnett square and breed each with another animal from your herd. (Note – you can choose more desirable genotypes/phenotypes from the punnett squares.)
From the pair on the left side of the paper:

**Breed:**

<p>| | |</p>
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**Genotypes:**

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</table>

**Punnett Square:**

<p>| | | |</p>
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</table>

From the pair on the right side of the paper:

**Breed:**

<p>| | |</p>
<table>
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<tr>
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<th></th>
</tr>
</thead>
</table>

**Genotypes:**

<p>| | |</p>
<table>
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**Punnett Square:**

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</table>
Each of the above four pairs each has two calves – each has one bull and one heifer. Below, identify the genotypes of offspring had by each pair (note – you can choose these based on the genotypes/phenotypes you wish to get out of the cross).

Reflect on your crosses. How did your herd fare – did you achieve your goal? What were the phenotypes of the offspring? Did all of the offspring end up with phenotypes you wanted or expected? What would you differently next time?
**Daily Plan**

<table>
<thead>
<tr>
<th>Lesson Title:</th>
<th>Animal Activist Positions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Title:</td>
<td>Animal Industry</td>
</tr>
<tr>
<td>Course:</td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>45 minutes</td>
</tr>
</tbody>
</table>

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

- Animal Activist Packet (one per group of 2-3 students) *Note – when creating these packets, be sure to include two blank slips of paper.*
- Animal Activist Positions handout (classroom set)

**Agriscience Foundations Standards:**

- 6.06 – Compare and contrast animal welfare issues.

**Essential Question:**

Why do traditionally harvested and cultured meat supporters each believe they are treating animals ethically?

**Daily Objectives**

1. Identify practices associated with animal welfare and animal rights.
2. Compare and contrast ideals of animal welfare and animal rights.

**Introduction (Interest Approach)**

<table>
<thead>
<tr>
<th>Estimated Time:</th>
<th>10 minutes</th>
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</table>

Ask students to consider whether they promote animal welfare or animal rights. As students give their answers, ask them to give a reason or example that supports their position.

*Guiding questions – Why do you feel that viewpoint (rights or welfare) is worth promoting? What actions do you take to support this position? Is there anything you disagree with regarding the other position? Does your position impact your decision regarding the production of lab grown meat?*
## Learning Activity 1

**Estimated Time:** 10 minutes

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Brief Content Outline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrange students into groups of 2-3. Give each group an Animal Activist Packet. Give the groups approximately 10 minutes to arrange the actions written on the pieces of paper into two groups – items supporting animal welfare and items supporting animal rights. Then have students use the two blank slips of paper to come up with one action or idea that would fit into each category.</td>
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</table>

## Learning Activity 2

**Estimated Time:** 10 minutes

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Brief Content Outline</th>
</tr>
</thead>
</table>
| Give each student a copy of the Animal Activist Positions handout. Have the student groups reevaluate their category assignments for the slips from Activity 1 and rearrange the slips as needed. During this time, students should also write the number of the rule from the handout that provides evidence that they put the action in the correct category. For example, if the action stated “limit the number of chickens house in one area”, the student should write “5” to correspond with the rule on the handout and the slip should be under “Animal Welfare”. Guiding questions – Why did you put that slip in that category? Which category do you think producers typically are in? Which category do you think those that promote lab grown meat are in? What about consumers? When students are finished labeling their slips with numbers, ask them to come up with and write down a definition for animal welfare and animal rights in their groups. | Animal Welfarists –  
1. Gentle animal handling  
2. Provide suitable diets and adequate water  
3. Provide living conditions that are well suited to the animals to reduce abnormal or injurious behavior  
4. Provide environments and equipment to prevent injury (penning, flooring, harnessing)  
5. Provide adequate space to prevent over-crowding  
6. Improve loading and transport to reduce bruises and injuries  
7. Use of appropriate techniques and equipment in slaughter process to minimize pain, fear, and distress  
8. Close attention to animals by caretakers improves potential for early diagnosis of disease and behavioral problems  
9. Vaccinate for diseases that can negatively impact animals  
Animal Rightists – (PETA)  
1. Eat non-animal produced diet (vegan)  
2. Purchase products that were not tested on animals  
3. Attend animal-free entertainment and recreation  
4. Adopt pets from shelters  
5. Spay and neuter pets  
6. Use organic gardening practices  
7. Lobby against animal industry practices |
Learning Activity 3

<table>
<thead>
<tr>
<th>Instructor Directions / Materials</th>
<th>Estimated Time: 10 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide students with the definition of animal welfare and animal rights. Ask students if their</td>
<td></td>
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<tr>
<td>definitions were accurate and if they included any additional aspects in their definitions.</td>
<td></td>
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<tr>
<td>Then ask students if they feel both types of activists are needed. *The teacher should guide</td>
<td></td>
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<tr>
<td>discussion toward the notion that both are needed in order to keep a system of checks and</td>
<td></td>
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<tr>
<td>balances in the industry.* After student discussion establishes that both types of activists</td>
<td></td>
</tr>
<tr>
<td>are needed in society, briefly go over some of the laws (listed to the right) that have been</td>
<td></td>
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<tr>
<td>developed through the work of animal welfarists and rightists.</td>
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</tbody>
</table>

**Brief Content Outline**

1. **Animal Welfare** – all animals should be happy, healthy, free from want, and treated humanely
   a. For animals to grow, reproduce, and perform, they must be well tended
      i. Provided with feed water, protection from parasites and disease, and protection from predators
   b. Most animal producers

2. **Animal Rights** – animals should have the same rights and privileges as humans.
   a. Animals shouldn’t be used for human benefit (food, clothes, pleasure, research)

3. **Laws related to animal welfare** – not an inclusive list
   a. Animal Transportation Act (1906)
   b. Humane Slaughter Act (1958)
   d. Horse Protection Act (1970)
   e. Marine Mammal Protection Act (1972)
   f. Improved Standards for Laboratory Animals Act (1985)
   g. Farm Animal and Research Facilities Protection Act (1989)
   h. Food, Agriculture, Conservation and Trade Act (1No0)
   i. Animal Enterprise Protection Act (1No2)
   j. Federal Law Enforcement Animal Protection Act (1No9)

**Summary (Review)**

<table>
<thead>
<tr>
<th>Estimated Time: 5 minutes</th>
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<tbody>
<tr>
<td>Ask students to consider what issues are identified as animal welfare issues. They should</td>
</tr>
<tr>
<td>individually create a list and bring the list to class on the following day.</td>
</tr>
<tr>
<td>Evaluation</td>
</tr>
<tr>
<td>--------------------</td>
</tr>
<tr>
<td>Students will be evaluated through their performance with the Animal Activist Packet slips and through classroom discussion.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Items Students Turn In</th>
</tr>
</thead>
<tbody>
<tr>
<td>None.</td>
</tr>
</tbody>
</table>
Cut these out to create packets of slips. Be sure to include two blank slips of paper.

**Animal Activist Packets**

<table>
<thead>
<tr>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don’t eat eggs, milk, or cheese.</td>
</tr>
<tr>
<td>Avoid the circus and zoo – go to the movies instead.</td>
</tr>
<tr>
<td>Specify a certain number of cattle to be transported together.</td>
</tr>
<tr>
<td>Use a non-electrified working stick to move cattle.</td>
</tr>
<tr>
<td>Fence in cattle to engage in rotational grazing.</td>
</tr>
<tr>
<td>Neuter your dog</td>
</tr>
<tr>
<td>Open second half of chicken house as birds grow to a larger size.</td>
</tr>
<tr>
<td>Get a puppy from petfinder.com instead of from a breeder.</td>
</tr>
<tr>
<td>Reduce noise in slaughterhouses.</td>
</tr>
<tr>
<td>Apply cow manure to gardens.</td>
</tr>
<tr>
<td>Provide animals with dietary supplements.</td>
</tr>
<tr>
<td>Check on animals daily.</td>
</tr>
<tr>
<td>Contact congressman to support legislation impacting animal industries.</td>
</tr>
<tr>
<td>Use farrowing crates when a sow has piglets.</td>
</tr>
<tr>
<td>Keep records on all animal vaccinations.</td>
</tr>
</tbody>
</table>
Animal Activist Positions

**Animal Welfarists** –

1. Gentle animal handling
2. Provide suitable diets and adequate water
3. Provide living conditions that are well suited to the animals to reduce abnormal or injurious behavior
4. Provide environments and equipment to prevent injury (penning, flooring, harnessing)
5. Provide adequate space to prevent over-crowding
6. Improve loading and transport to reduce bruises and injuries
7. Use of appropriate techniques and equipment in slaughter process to minimize pain, fear, and distress
8. Close attention to animals by caretakers improves potential for early diagnosis of disease and behavioral problems
9. Vaccinate for diseases that can negatively impact animals

**Animal Rightists** – (PETA)

1. Eat non-animal produced diet (vegan)
2. Purchase products that were not tested on animals
3. Attend animal-free entertainment and recreation
4. Adopt pets from shelters
5. Spay and neuter pets
6. Use organic gardening practices
7. Lobby against animal industry practices
## Daily Plan

<table>
<thead>
<tr>
<th>Lesson Title:</th>
<th>Animal Activist Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Title:</td>
<td>Animal Industry</td>
</tr>
<tr>
<td>Course:</td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>45 minutes</td>
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</tbody>
</table>

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

- Classroom set of computers with internet access
- List of activist organizations (can be handed out to students, displayed over a projector, or written on the board)
  
  *Note – due to the graphic content included in some of the listed websites, teachers may omit some of these or guide students to limited pages in the websites. To achieve this, teachers should review the websites before class to determine an appropriate course of action.*

- Argument Development Guide (classroom set)

**Agriscience Foundations Standards:**

- 6.06 – Compare and contrast animal welfare issues.

**Essential Question:**

Why do traditionally harvested and cultured meat supporters each believe they are treating animals ethically?

**Daily Objectives**

1. Identify organization practices that support positions on animal issues.
2. Develop and justify an argument supporting a position regarding an animal issue.

## Introduction (Interest Approach)

**Estimated Time: 10 minutes**

Ask students to share their list of animal welfare issues that they developed at the end of the previous class. Develop a classroom list that compiles student lists.

*Note – some examples of issues are located in the unit plan:*

- Animal transportation
- Slaughter
o. Pre-slaughter management  
p. Provision of adequate feed and water  
q. Handling of animals by humans  
r. Culling of animals that are unhealthy or of low commercial value  
s. Housing conditions

*Guiding questions* – *Why do you think that is an issue? Where have you seen or heard of it being an issue? Do you think this is an issue raised by animal rightists or welfarists?*

<table>
<thead>
<tr>
<th>Learning Activity 1</th>
<th>Estimated Time: 30 minutes</th>
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<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
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</tbody>
</table>
| Have each student get a computer and choose one animal activist issue he/she has interest in. Using the activist organization websites, have students write a letter to the organization either in support of or in opposition to the organization’s position on the issue. Give each student a copy of the Argument Development Guide to include appropriate items in their letters. Letters should be turned in at the end of class. | 1. Claim  
2. Warrant(s)  
3. Backing  
4. Data/Grounds  
5. Reservation  
6. Qualifier |

*Note* – *Due to the open-ended nature of the assignment and the graphic content included on the websites, students should be closely monitored to keep them on task.*

*Guiding questions* – *Why did you choose this issue? What is this organization’s stance on the issue? What do you plan to write to them? What backing do you have? What grounds do you have? Are there any reservations?*

Letters should be turned in at the end of class.
### Summary (Review)
Estimate time: 5 minutes

If time allows, hold a brief class discussion regarding student reactions to organizations’ positions regarding certain issues.

*Guiding questions* – Did the organization’s information make you second-guess your position on the issue? What tactics does the organization use to convince people of their position? What items did you include in your letter to support your own position?

### Evaluation

Students will be evaluated through their animal activist organization letters.

### Items Students Turn In

Letters to animal activist organizations
Argument Development Guide

When developing an argument, the following items just don’t cut it:
- “Uh-huh.”
- “Because I said so.”
- “That’s stupid.”

In order to develop an argument that might convince someone to see things your way, the argument should contain several components:

1. **Claim**
   a. A claim is the major position of an argument, such as, "I deserve an 'A' in this class.'
   b. Arguments can have the claim at the beginning or end, but all other parts of the argument should support this claim.

   Write your claim here:

2. **Warrant(s)**
   a. A warrant leads directly to a claim – it states some of the reasons you are making your claim.
   b. A warrant is the (one of the) reason(s) given to lead a reader to accept the claim. For example, "I worked really hard in this class; therefore, . . . ."
   c. Arguments can have more than one warrant to justify a single claim.

   Outline your warrants here:

3. **Backing**
   a. A backing leads to a warrant, encouraging a reader to believe the warrant is true.
   b. A backing offers something intended to assure a reader that a warrant is credible, such as "If you doubt me, you can check my personal journal."
   c. Backing can also include references if you are not considered an expert on the topic: “As noted in Journal XYZ, Author A says…”

   List your backings here:
4. **Data/Grounds**  
a. Data (or grounds) are specific evidence offered to support the salient claim, such as:  
   i. "Each advisory grade I received for the assigned projects I submitted was an 'A'."  
   ii. "Also, I got a 'check' mark or a 'plus' mark on every activity I submitted."

   **List your data here:**

5. **Reservation**  
a. A reservation may be associated with a claim, warrant, backing, or data/grounds.  
b. A reservation may be used to anticipate and discount a reader's objection to a claim, warrant, backing, or data/grounds. For example, a reservation to the data offered about project grades could be "Of course, I can't be responsible for my instructor failing to correctly record one or more of my project grades."

   **List potential reservations that the reader might be thinking here:**

6. **Qualifier**  
a. A qualifier "softens" a claim, since most claims cannot be absolutely true or necessary in all cases.  
b. A qualifier usually includes a word which indicates a degree of truth or necessity, like almost, possibly, likely, most likely, et cetera.

   **List qualifiers to your claim here:**

Now, outline your argument on a separate sheet of paper. Determine where you will place each of the above items in your argument, and list out the above details you offered, as well as any other additions you wish to make. Your argument is ready!
Animal Activist Organizations

People for the Ethical Treatment of Animals – www.peta.org
Issues of Focus –
- Animals used for food
- Animals used for clothing
- Animals used for experimentation
- Animals used for entertainment
- Companion animals
- Wildlife

Ducks Unlimited – www.ducks.org
Issues of Focus –
- Conservation of wetlands
- Conservation of waterfowl

Issues of Focus –
- Caring for pet parents and pets
- Providing positive outcomes for at-risk animals
- Serving victims of animal cruelty

Humane Society of the United States – www.humanesociety.org
Issues of Focus –
- Animal cruelty and fighting
- Farm animal protection
- Puppy mills
- Wildlife abuses
- Fur trade
- Chimpanzees
**Daily Plan**

<table>
<thead>
<tr>
<th>Lesson Title:</th>
<th>Animal Industry Posttest</th>
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<tbody>
<tr>
<td>Unit Title:</td>
<td>Animal Industry</td>
</tr>
<tr>
<td>Course:</td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>45 minutes</td>
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</table>

**Materials, Supplies, Equipment, References, and Other Resources:**
- Animal Industry Posttest (classroom set)
- Fetal Bovine Serum article (classroom set)

**Agriscience Foundations Standards:**
- 6.03 – Illustrate correct terminologies for animal species and conditions within those species.
- 6.02 – Categorize animals according to use, type, breed, and scientific classification.
- 6.04 – Compare the basic internal and external anatomy of animals.
- 3.07 – Investigate DNA and genetics applications in agriscience including the theory of probability.
- 6.06 – Compare and contrast animal welfare issues.
- 3.03 – Identify the parts and functions of plant and animal cells.
- 3.04 – Describe the phases of cell reproduction.

**Essential Question:**
Why do traditionally harvested and cultured meat supporters each believe they are treating animals ethically?

**Daily Objectives**
1. Display knowledge regarding the animal industry through a posttest.
2. Evaluate practices regarding lab grown meat in relation to animal welfare and rights ideals.

**Introduction (Interest Approach)**

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<th>Estimated Time:</th>
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Explain to students that they will be taking the animal industry posttest.
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<tr>
<th>Learning Activity 1</th>
<th>Estimated Time: 25 minutes</th>
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<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
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<tr>
<td>Students will complete the animal industry posttest. Teachers should ensure that appropriate testing conditions are maintained. Tests should be turned in upon completion.</td>
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<tr>
<th>Learning Activity 2</th>
<th>Estimated Time: 10 minutes</th>
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<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>Ask students to consider how animal welfarists and rightists would react to the production of lab grown meat. Once several student answers have been voiced, have students read the Fetal Bovine Serum Article. <em>Note – if time is limited, have students stop reading after the first few sentences of the section on animal rights issues with FBS.</em></td>
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<thead>
<tr>
<th>Summary (Review)</th>
<th>Estimated Time: 5 minutes</th>
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</table>
| Ask students to once again consider how animal welfarists and rightists would react to the production of lab grown meat.  

*Guiding questions – Did the article change your mind about what these groups might think about lab grown meat? Do you think activists know that cattle must be killed in order to culture the meat cells? How is this issue addressed (or not addressed) by promoters of lab grown meat? Do you think this is ethically responsible of them? Why or why not?* |

<table>
<thead>
<tr>
<th>Evaluation</th>
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<tbody>
<tr>
<td>Students will be evaluated through their animal industry posttests.</td>
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<table>
<thead>
<tr>
<th>Items Students Turn In</th>
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<tbody>
<tr>
<td>Animal Industry Posttests</td>
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FBS Use in Cell Cultures: The Beginning of the End?

By Kelly C. Westfall

For years, animal sera have been used to enhance cell culture growth. Serum, including fetal bovine serum (FBS) and non-fetal bovine serum, contains nutritional aspects, which are vital for successful growth of animal cell cultures. Because of its exceptional growth enhancement properties, FBS is more widely used than non-fetal bovine sera (such as adult bovine, horse, goat, and swine sera).

Advantages of FBS Over Other Sera

FBS is the preferred animal serum for cell culture enhancement for several reasons. It has an abundance of proteins, growth factors, enzymes and other chemical components that make it ideal for promoting cell health and growth. All animal fetuses are generally well protected by the placenta and the chance of serum contamination by pathogens in vivo is minimal when compared to the contamination potential of an adult. However, fetal cows are used as a serum source more often than other animals because cattle are plentiful, slaughtered in high volumes, and yield multiple end products. The fetal bovine immune system is not mature and contains fewer molecules (such as complement and antibodies) that could interfere or inhibit the growth of cells.

Conflicts Over the Use of FBS

The use of FBS raises questions in the minds of animal rights activists and regulating agencies. Since FBS is a byproduct derived from fetal blood, pregnant cows must be slaughtered to obtain it. This practice does not appeal to animal rights activists. Also, fairly recent outbreaks of diseases such as bovine spongiform encephalopathy (mad cow disease) and foot and mouth disease (FMD) have driven regulatory agencies to pay scrupulous attention to the uses of cell culture products that have been grown using bovine serum. Understandably, the Food and Drug Administration (FDA) is especially stringent over products made with FBS that will be ingested or
implanted, such as pharmaceuticals and human tissue. Although extensive testing has adequately ensured the safety of FBS, these issues could be greatly reduced by closely analyzing alternatives to serum. These conflicts remain on the forefront; particularly when there are some reliable alternatives to using animal sera. In addition to progressively successful research in serum-free media development, issues with regulatory agencies could, consequently, help drive the FBS market to eventual extinction.

**Serum-Free Methods May Replace FBS**

Although FBS has not been perfectly defined in biochemical terms, some advancements and discoveries have been made. Because of this, consistencies in serum lots have improved significantly over the past few years resulting in better cell culture product consistency and less time consuming testing for lot-to-lot variations. Furthermore, the recognition of increased serum definition has led many biotechnology firms to develop and market serum-free media. This media eliminates the requirement of serum for growing cells. However, serum-free media has to be specialized for certain cell lines and there is not, of yet, any serum-free media that can maintain a very broad selection of cell lines with notable results. Incidentally, the driving factor behind FBS production is not demand, but the state of the cattle industry. But with the encouragement of the FDA and the US Department of Agriculture (USDA), advancements in universal serum-free media may not be improbable in the near future.

**The FBS Market**

The FBS market is mature and relatively static, growing only slightly each year. With the proliferation of serum-free and protein-free media in the marketplace, the FBS market should become flat and, eventually, experience a gradual decline in growth. This market decline, however, does not indicate the decline of the use of cell cultures. The growth of cells is no longer 100% dependent upon the use of FBS and the uses of cell cultures and their end products have increased. Finally, since production of FBS is largely dependent upon the cattle industry, revenues from serum-free media may be more consistent as its sales will be dependent upon demand.
<table>
<thead>
<tr>
<th>Daily Plan</th>
<th>Socio-Scientific Issues Instruction – Day 44</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lesson Title:</strong></td>
<td>Argument Development and Defense</td>
</tr>
<tr>
<td><strong>Unit Title:</strong></td>
<td>Introduction of Cultured Meat</td>
</tr>
<tr>
<td><strong>Course:</strong></td>
<td>Agriscience Foundations</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>45 minutes</td>
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**Materials, Supplies, Equipment, References, and Other Resources:**

Six large sheets of art or butcher paper, each with one of the following headings:
- Animal Production Industry
- Animal Welfare
- Economy
- Environment
- Food Safety
- Other
Markers (one per student)
Question wall from the beginning of the unit
Argumentation Posttest (classroom set)

**Agriscience Foundations Standards:**

3.08 – Evaluate advances in biotechnology that impact agriculture (e.g. transgenic crops, biological controls, etc.)
9.03 – Identify and demonstrate ways to be an active citizen.
9.05 – Demonstrate the ability to work cooperatively.

**Essential Question:**

How would the incorporation of cultured meat into the nation’s food supply impact consumers, the agricultural industry, the environment, and the economy?

**Daily Objectives**

1. Create multi-faceted arguments defending a particular position regarding the production of lab grown meat.
2. Evaluate the benefits and drawbacks of lab grown meat production.
**Introduction (Interest Approach)**

**Estimated Time: 5 minutes**

Lay each sheet of butcher paper in a separate area around the room. Tell students to visit each sheet of paper and write down one piece of evidence that either supports the production of lab grown meat (labeled with a plus sign) or opposes the production of lab grown meat (labeled with a minus sign). Students should visit as many sheets as they can before time is up.

*Note – This is a limited class time activity. To increase classroom organization, the teacher may divide students up into groups that stay together as they travel to each of the pieces of paper. If this approach is used, the teacher will time students at each paper and call out for them to switch locations or rotate to each paper.*

<table>
<thead>
<tr>
<th>Learning Activity 1</th>
<th>Estimated Time: 10 minutes</th>
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</thead>
<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>Have students examine the remaining questions on the question wall that was developed on the first day of the nine week unit. Based on the number of cards left, the teacher may arrange students accordingly (ex – each student picks a card, students get into partners and pick a card, etc.). Students should remove all cards from the wall and determine whether the question they chose has been answered through the class. If the question has been answered, the student should make sure that the corresponding piece of butcher paper contains evidence related to the question’s answer. If the question has not been answered, the student should add the question to the appropriate butcher paper.</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Learning Activity 2</th>
<th>Estimated Time: 10 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>Spending about 1-2 minutes on each sheet of paper, guide the class through a brief summary of the major points listed on each sheet. If any questions from the wall are unanswered, ask the class to determine ways they might find out the answers to these questions.</td>
<td></td>
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</tbody>
</table>

*Guiding questions – Which pieces of evidence on this sheet were influential in your decision making, or which supported your position best? How might we go about answering that remaining question?*
<table>
<thead>
<tr>
<th>Learning Activity 3</th>
<th>Estimated Time: 20 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instructor Directions / Materials</strong></td>
<td><strong>Brief Content Outline</strong></td>
</tr>
<tr>
<td>Have students complete the Argumentation Posttest. The teacher should ensure that appropriate testing conditions are maintained. Tests should be turned in upon completion.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Summary (Review)</th>
<th>Estimated Time: 10 minutes</th>
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<tbody>
<tr>
<td>Due to the posttest administration, there will be no review.</td>
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<table>
<thead>
<tr>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will be evaluated on their argumentation posttests.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Items Students Turn In</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argumentation Posttest</td>
</tr>
</tbody>
</table>
# APPENDIX B
## UNIT CONTENT

<table>
<thead>
<tr>
<th>Food Safety Unit Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit Name:</strong> Food Safety</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong> 1 Week</td>
</tr>
<tr>
<td><strong>Essential Questions:</strong></td>
</tr>
<tr>
<td>1. Why are consumers concerned with food safety?</td>
</tr>
<tr>
<td>2. How is food safety impacted by agricultural production practices?</td>
</tr>
<tr>
<td>3. How can the animal and food industries improve food safety?</td>
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</tbody>
</table>

## Essential Question 1: Why are consumers concerned with food safety?

<table>
<thead>
<tr>
<th>Agriscience Foundations I Standards:</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.08 – Evaluate advances in biotechnology that impact agriculture (e.g. transgenic crops, biological controls, etc.).</td>
</tr>
<tr>
<td>1.04 – Examine the role of the agricultural industry in the interaction of population, food, energy, and the environment.</td>
</tr>
<tr>
<td>3.06 – Interpret, analyze, and report data.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objectives:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will be able to:</td>
</tr>
<tr>
<td>1. Identify biotechnological innovations that have impacted the food supply.</td>
</tr>
<tr>
<td>2. Evaluate the potential benefits and drawbacks of advancements in biotechnology.</td>
</tr>
<tr>
<td>3. Identify historical events that have led consumers to elicit concern regarding food safety.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective 1:</th>
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<tbody>
<tr>
<td>Identify biotechnological innovations that have impacted the food supply.</td>
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<table>
<thead>
<tr>
<th>Content Outline:</th>
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<tbody>
<tr>
<td>3. Terminology</td>
</tr>
<tr>
<td>a. Biotechnology – using organisms and their components to make products (includes GMOs)</td>
</tr>
<tr>
<td>b. Genetically modified foods – alters the genetic makeup of organisms (plants, animals, bacteria). AKA genetically engineered, transgenic</td>
</tr>
<tr>
<td>4. Food biotechnology’s current status:</td>
</tr>
<tr>
<td>a. Hybrid plant varieties became commercially available in 1930s, and greatly increased crop yields</td>
</tr>
<tr>
<td>b. The creation of the first genetically engineered farm animals was documented in 1985</td>
</tr>
<tr>
<td>c. In 2006, 252 million acres of transgenic crops were planted in 22 countries</td>
</tr>
<tr>
<td>i. 53% was in the US</td>
</tr>
</tbody>
</table>
d. In 2009, over 330 million acres of biotech crops were grown

e. The first medical product from a genetically engineered animal was approved by US govt. in 2009

f. The practical benefits of this technology have not yet reached American patients and consumers, however continued successful application of the new United States (U. S.) federal government regulatory process should be aggressive, enabling scientific innovation.

5. Goals of food biotechnology’s innovations:

a. Overcome agricultural limitations
   i. Salt tolerant plants
      1. Used to grow crops on land with water that has high salt content (otherwise would be nonproductive)
   ii. Increase in milk production in dairy cows
      1. Uses bST hormone that cows naturally produce, inject more bST into the cow to produce more milk
   iii. Increase growth rates with hormones in cattle, fish, pigs, sheep
   iv. Fruit and nut trees that yield years earlier than they do naturally
   v. Drought or flood resistant crops

b. Increase food quality
   i. Shelf life
      1. Flavr Savr tomato
   ii. Pest resistance
      1. Corn
      2. Soybeans
      3. Cotton
      4. Canola
      5. Alfalfa
   iii. Disease resistance
      1. In cattle (mad cow disease [BSE], chickens, fish, pigs
      2. Sweet potatoes that are resistant to a virus that could kill most of Africa’s harvest
   iv. Taste
      1. Increase meat tenderness with product that knocks out acid-meat gene

c. Improve human health
   i. Disease management
      1. Lactose fortified milk
   ii. Disease prevention
      1. Fortified milk
      2. Reduce “bad” fats and increase “good” fats of plant oils (like Omega-3 fatty acids)
3. Reduce fat and cholesterol in meat of cattle and pigs
4. Rice with increased iron and vitamins (Golden rice has beta carotene, which is Vitamin A)
5. Bananas that produce human vaccines against diseases like hepatitis B

d. Minimize environmental impact
   i. Reduce waste excreted by enhancing growth rate of fish, cattle, and pigs
   ii. Detect pollutants more easily with use of GloFish
   iii. Increase nitrogen use efficiency to require less nitrogen fertilizer
   iv. Enviropig – line of Yorkshire pig that is able to digest phosphorus in grains, which keeps the amount of phosphorus in manure lower
   v. Goat with spider silk – use less natural resources for building

Objective 2: Evaluate the potential benefits and drawbacks of advancements in biotechnology.

Content Outline:

1. Food Quality
   a. BENEFIT – enhanced taste and quality
      i. Longer shelf life, better coloring, less disease, improved marbling

2. Food Safety
   a. BENEFIT – foodborne diseases are a major global contributor to human death and illness
      i. Could produce foods that are resistant to food borne pathogens (E.coli, salmonella, ect.)
      ii. Could reduce animals’ ability to contract zoonotic diseases (those passed between animals and humans)
   b. DRAWBACK – new regulations that do not have an established successful history
      i. GMO labeling is currently not mandatory in some countries (like the US)
   c. DRAWBACK - bioterrorism

3. Economic Impacts
   a. BENEFIT – cheaper, more available foods
      i. Fewer costs to produce foods because of less fertilizer, pesticides, supplemental dietary additives, feed, water, and medical care. Also, more food is available, increasing supply leads to cheaper foods
   b. DRAWBACK – domination of world food production by a few companies
      i. Increased dependence on certain nations with reduced food independence

4. Environmental Impacts
   a. BENEFIT – agricultural industries have been targeted by some as being harmful to the environment due to use of pesticides, fertilizers, and causing increased water, land, and air pollution. GMOs can reduce fertilizer and pesticide usage, increase animal and plant efficiency in their use of certain nutrients, and reduce animal wastes
   b. BENEFIT – higher yielding animals and plants will reduce the burden on limited land and water resources
   c. DRAWBACK – unknown effects on other organisms
      i. Can impact entire ecosystems in ways we don’t yet know
      ii. Unintended transfer of genes through accidental cross-pollination
5. Human Health
   a. **BENEFIT** - Could greatly reduce diseases that result from poor diet of high fats and low quality protein (cardiovascular disease, cancers, diabetes, obesity)
      i. Health and cognitive skills improve with increased nutrition
         1. A limited land supply means agriculturalists must develop more nutritional foods on the same amount of land, since they can’t simply produce more food on more land
      ii. Childhood obesity is a nationwide epidemic
         1. Leaner meats and oils with “good” fats and fewer “bad” fats can decrease obesity
   b. **DRAWBACK** – unknown effects of GMOs on human health
      i. Allergies, transfer of antibiotic resistance to humans, etc.

6. Plant and Animal Industry
   a. **BENEFIT** – fewer resources (feed, land, etc.) will be needed to produce more food
      i. Animals with greater feed efficiency and better quality/more meat production on less food and with fewer supplements
      ii. Plants yield more on same amount of land with less water and fertilizer and in more varied weather and soil conditions
      iii. Improved reproductive performance can yield more offspring with desirable traits through fewer breedings
   b. **DRAWBACK** – smaller farmers may get pushed out of industry by more powerful companies
   c. **DRAWBACK** – unknown long term effects of gene manipulation on breeds and species
      i. Reduction of genetic variety in a species

7. Animal Welfare
   a. **BENEFIT** – Can reduce animals’ susceptibility to disease and illness – mad cow disease, mastitis, foot and mouth disease, etc., which will decrease animal stress and suffering
      i. Will reduce need for medical treatments and use of antibiotics
   b. **DRAWBACK** – could cause unknown stress for animals

8. Ethics
   a. **BENEFIT** – improvement of global human health and reduction of human death, disease, poverty, and hunger
   b. **DRAWBACK** – tampering with nature by mixing genes among species
      i. Some people may be opposed to eating the genes of animals in plant foods, vice versa

| Objective 3: | Identify historical events that have led consumers to elicit concern regarding food safety. |
7. Beef
   a. E. coli
      i. 2005 – 5 beef recalls related to E. coli
      ii. 2006 – 8 recalls
      iii. 2007 – 21 recalls
   b. Mad Cow Disease (Bovine Spongiform Encephalopathy)
      i. Largest beef recall in US history in 2008 (143 million lbs) after videos of down cows going to slaughter were released by Humane Society of U.S.
      ii. 
   c. Foot and Mouth Disease
      i. First outbreak in Britain in over 20 years was in 2001, led to ban of all British exports of meat, livestock, and milk. 7 million sheep and cattle were killed to stop disease spread
   d. Hormone additive controversy
8. Swine
   a. H1N1
      i. Outbreak in 2009 US show swine and humans caused some countries (China, Russia, Ukraine) to ban pork coming from Mexico and US, and Egypt to slaughter 300,000 pigs, although swine flu is not spread through eating infected pork. Confusion led World Health Organization to stop using the term “swine flu”.
9. Poultry
   a. Avian Influenza
      i. First reported in animals and humans (some died) in 1No7 in Hong Kong. Spread through Asian countries’ poultry and humans on a sporadic basis, then moves to Europe in 2006. US sees first cases in wild birds in 2006. Live poultry markets are permanently closed in Beijing and China
10. Lettuce
    a. Bagged salad was linked to E. coli outbreaks in 2006, 2010, and 2011
11. Peanut Butter
    a. 2007 outbreak of Salmonella in Peter Pan and Great Value peanut butters
    b. 2009 outbreak of Salmonella in King Nut peanut products
12. Sprouts
    a. E. coli outbreak Germany in May 2011, killed 49, over 800 developed life threatening kidney complication. Contaminated seeds from Egypt are thought to be the cause.

Essential Question 2: How is food safety impacted by agricultural production practices?

Agriscience Foundations 2.03 – Evaluate the food safety responsibilities that occur along the food supply chain.
<table>
<thead>
<tr>
<th>I Standards:</th>
<th>6.05 – Demonstrate scientific practices in the management, health, safety, and technology of the animal agriculture industry. 4.04 – Identify regulatory agencies that impact agricultural practices.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives:</td>
<td>Students will be able to: 1. Identify agricultural organizations’ roles in the production of a safe food supply. 2. Analyze the impact of current agricultural practices on food safety.</td>
</tr>
<tr>
<td>Objective 1:</td>
<td>Identify agricultural organizations’ roles in the production of a safe food supply.</td>
</tr>
</tbody>
</table>
| Content Outline: | 5. USDA –  
| a. | The **Agricultural Marketing Service (AMS)** - administers plant variety and seed laws, including GM seeds, and administers laws for certification and labeling of seeds for trade. AMS also offers laboratory testing services for GM foods and fiber products and *voluntary* process verification services to assure separation of GM and conventional products in food chain.  
| b. | The **Agricultural Research Service (ARS)** conducts research in new traits and improving existing traits in livestock, crops, and microorganisms; safeguarding the environment; and assessing and enhancing the safety of biotechnology products. ARS also develops and provides access to agricultural resources and genomic information.  
| c. | The **Animal and Plant Health Inspection Service (APHIS)** regulates field-testing, interstate movement, and importation of GMOs. APHIS determines whether a GMO is as safe for the environment as its traditionally bred counterpart and can be freely used in agriculture.  
| d. | The **Economic Research Service (ERS)** conducts research on the economic aspects of the use of GMOs, including the rate of and reasons for adoption of biotechnology by farmers. ERS also addresses economic issues related to the marketing, labeling, and trading of GMOs.  
| e. | The **Food Safety and Inspection Service (FSIS)** is the public health agency in the U.S. Department of Agriculture responsible for ensuring that the nation's commercial supply of meat, poultry, and egg products is safe, wholesome, and correctly labeled and packaged including animals involved in biotechnology.  
| f. | USDA's **Foreign Agricultural Service (FAS)** supports the overseas acceptance of biotechnology and crops that have been reviewed by the U.S. government agencies to support U.S. farm exports and promote global food security.  
| g. | The **Grain Inspection, Packers and Stockyards Administration (GIPSA)** provides inspection, weighing, and related services on grains, pulses, oilseeds, and processed and graded commodities. GIPSA also oversees a *voluntary* process verification program which allows suppliers to assure customers about the quality of their products or services through independent audits of their manufacturing practices or services.  
| h. | The **National Agricultural Statistics Service (NASS)**, as the fact finder for agriculture, provides information on |
the adoption of biotechnology crops (specifically corn, cotton, and soybeans). NASS has been tracking the adoption of biotech crops since 2000.

i. The **National Institute of Food and Agriculture (NIFA)** provides funding and program leadership for research in agricultural biotechnology. Also supports the development of science-based information regarding the safety of introducing into the environment genetically-modified plants, animals, and microorganisms.

6. **FDA**

   a. FDA is the federal agency responsible for ensuring that foods are safe, wholesome and sanitary; human and veterinary drugs, biological products, and medical devices are safe and effective; cosmetics are safe; and electronic products that emit radiation are safe. FDA also ensures that these products are honestly, accurately and informatively represented to the public. Some of the agency's specific responsibilities include:

   i. **Foods**
      1. Labeling
      2. safety of all food products (except meat and poultry)
      3. bottled water

   ii. **Veterinary Products**
      1. Livestock feeds
      2. Pet foods
      3. Veterinary drugs and devices

   b. Doesn’t regulate alcohol, meat and poultry, pesticides

7. **CDC**

   a. Works with USDA and FDA to ensure food safety. Acts as agency that connects consumer illness with food production processes through:

      i. Monitoring human illness and tracking illness occurrences
      ii. Identifying the foods and settings linked with illness
      iii. Investigating outbreaks and cases
      iv. Working with state and local health departments
      v. Targeting prevention measures to meet long-term food safety goals
      vi. Informing food safety action and policy

8. **EPA**

   a. FDA, USDA, and the Environmental Protection Agency share the responsibility for regulating pesticides. EPA determines the safety and effectiveness of the chemicals and establishes tolerance levels for residues on feed crops, as well as for raw and processed foods.

<table>
<thead>
<tr>
<th>Objective 2:</th>
<th>Analyze the impact of current agricultural practices on food safety.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content Outline:</td>
<td>5. Beef Industry</td>
</tr>
<tr>
<td>a.</td>
<td>Calves are vaccinated, castrated, implanted, dehorned</td>
</tr>
</tbody>
</table>
b. Cattle are given additives in feed
   i. Antimicrobial Drugs
   ii. Animals raised in confinement hold greater potential for spread of harmful microbes, so antimicrobial drugs keep these under control
   iii. Used at a lower level in the feed than if the animal was sick (subtherapeutic level)
   iv. Has been used less frequently recently because of concern about the development of resistant strains of bacteria
   v. Hormones
   vi. Normally produced in the body to regulate body functions (growth, metabolism, reproductive cycle, etc)
   vii. Hormones and synthetic hormones are added to stimulate certain functions
   viii. Synthetic hormones are approved by the FDA for use in beef cattle finishing rations
      a. DES was used as a synthetic estrogen to increase rate of gain in steers, but was banned in 1972 because of cancers in women when used to prevent miscarriages. Ban was lifted and then banned again by 1979.
      b. Cases like this continue to make use of hormones controversial
      c. Since 1989 European Union banned importation of any meat for human consumption that has been treated with hormones
      d. Problematic because it is not possible to differentiate between hormones injected and those produced by the animal
      e. In 1No8, World Trade Organization ruled that EU ban was a violation of international trade rules, but studies showing harmful effects of one growth hormone keep the ban in effect.
   ix. Dewormers – control parasites

c. Processing
   1. Feed additives and drugs are removed from feed for a specified amount of time before slaughter
   ii. Feed is adjusted to condition animals for travel
   iii. Cattle are moved slowly and quietly when loading and handling to keep animals relaxed and keep meat cuts high quality
   iv. Trucks are loaded without crowding or underloading to reduce animal injury

d. To increase food safety
   i. Producers encouraged to attend Beef Quality Assurance Training.
   ii. Irradiation of ground beef products is done by packers and meat retailers to kill bacteria (like E. coli)
   iii. Educational efforts encourage consumers to cook hamburger thoroughly, clean utensils and surfaces
   iv. It’s illegal to feel animal products to cattle that may transmit the organism for mad cow disease
   v. Country of origin labeling
vi. Mandatory identification allow verification of origin of beef products

6. Swine Industry
   a. Piglets
      i. Umbilical cord cut, remaining cord sprayed with iodine
      ii. Cut needle teeth (8 sharp teeth) – tips are removed at one day old to prevent cuts on other piglets and sow’s udder (reduces risk of infection)
      iii. Some large commercial operations have abandoned this practice and experience few problems
      iv. Tail docking at one day old - reduces chance of tail biting (older pigs fed in confinement may bite other pigs’ tails)
      v. Ear notching – identification of individual pigs. More permanent than ear tags
      vi. Receive dose of long-lasting antibiotic to ward off infection
      vii. Receive iron injection at 7 days old b/c sow milk is low in iron (prevents anemia)
      viii. Injections given on neck 1 inch behind ear to avoid abscesses or iron stain in ham muscle
      ix. Boars are castrated at 3-7 days of age to reduce stress
   b. To increase food safety
      i. Welfare audits lead large eating establishments to pressure packers to verify that pork was raised under acceptable production conditions
      ii. Packers require their producers to maintain Pork Quality Assurance certification from National Pork Board
         1. National Pork Board provides a voice for producers nationwide and develops promotional/educational materials
            a. 15 producers are appointed by US Secretary of Ag.
      iii. Producers follow 10 good production practices to ensure pork quality
      iv. Producers practice biosecurity
      v. 2002 Farm Bill – Congress mandated country of origin labeling
         1. National Pork Producers Council tracks legislative issues for pork producers

7. Poultry Industry
   a. Animal Management
      i. Raised in confinement in an open-floor system
      ii. House is cleaned and disinfected each time a flock leaves, wait one week for new flock to come in
      iii. Ventilation will prevent respiratory diseases and will reduce ammonia odor
      iv. Chickens may be debeaked to prevent cannibalism (1/3 of upper beak and ¼ of lower beak is removed). Does not affect growth or health of chickens
      v. Hormone implants may be used to produce same results as castrating (surgically castrating males). This
causes chickens to produce more tender meat.

b. Processing
   i. Should not be fed 12 hours before slaughter
   ii. Avoid overcrowding in delivery coops

8. Dairy Industry
   a. Animal Management
      i. Feeding needs vary by cow status (pregnant, milking, dry, calf, bull)
      ii. Vitamin and mineral supplementation varies by amount of feed, which varies on lactation period
      iii. Forages are tested for nutritional quality every 60 days
   b. Processing
      i. Cow’s udders are washed to disinfect udder and trigger release of oxytocin, which initiates milk letdown
      ii. Teats are dipped in iodine to prevent bacterial invasion of udder

Essential Question 3: How can the animal and food industries improve food safety?

<table>
<thead>
<tr>
<th>Agriscience Foundations I Standards:</th>
<th>2.03 – Evaluate the food safety responsibilities that occur along the food supply chain.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.05 – Demonstrate scientific practices in the management, health, safety, and technology of the animal agriculture industry.</td>
<td></td>
</tr>
<tr>
<td>4.04 – Identify regulatory agencies that impact agricultural practices.</td>
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</tbody>
</table>

Objectives:

Students will be able to:
1. Compare current agricultural practices and consumer concerns to determine areas of improvement for food safety.
2. Evaluate the potential benefits and drawbacks of possible solutions to current food safety issues.

Objective 1:

Compare current agricultural practices and consumer concerns to determine areas of improvement for food safety.

Content Outline:

3. Food Quality
   a. Public Concerns – inconsistency in product quality, cost versus quality, shelf life
   b. Current Solutions -
      i. food additives – increase consistency in quality, but some are concerned with potential human health effects
      ii. preservatives – increases food shelf life, but some are concerned with potential human health effects
      iii. pesticides – increases consistency in quality, produces more attractive products, but some are concerned with potential human and environmental effects
      iv. organic choices – don’t contain pesticides, but are typically more expensive and less attractive (bug spots, etc.)
      v. GMOs – reduces use of pesticides and increases consistency in quality, but some are concerned with potential human and environmental effects
4. Food Safety
   a. Public Concerns – contamination through processing, allergens, lack of consistent regulation, bioterrorism, lack of knowledge of GMO impacts
   b. Current Solutions –
      i. Current regulation and inspection standards by USDA, FDA, EPA, and CDC, and Department of Homeland Security
      ii. Buy locally – reduced processing, can be costly, reduces product availability
      iii. Organic choices – reduces food additives, can be costly

5. Economic Impacts
   a. Public Concerns – high cost of quality foods, world hunger
   b. Current Solutions –
      i. Public assistance – available to purchase specific healthy foods to those below a certain income level
      ii. Food warehouses/Large store chains – can purchase more food for less cost, and pass savings to customer (Ex – food at Walmart is typically cheaper than at a convenience store or a local food store)
      iii. GMOs – can greatly reduce world hunger and the cost of food because of less cost input required to produce foods, but some countries won’t import GMOs due to health and safety concerns

6. Environmental Impacts
   a. Public Concerns – agriculture industry’s impact on water, soil, and air pollution, due to pesticide and manure runoff and resource usage
   b. Current Solutions –
      i. Increased governmental regulation on pollution runoff and output levels
      ii. Organic farming – reduces use of pesticides
      iii. GMOs – reduces use of pesticides and waste produced by animals (increased feed efficiency and fewer animals with higher yields)

7. Human Health
   a. Public Concerns – food safety recalls from foods infected with diseases, poor diets (high fat, low nutrition) lead to disease (diabetes, obesity, cardiovascular disease), increasing prevalence of food allergies among children
   b. Current Solutions –
      i. Current food regulation and inspection by USDA, FDA, and CDC
      ii. Enriched and fortified foods contain nutrients not normally found in that product (Iodized salt, Vitamin A & D fortified milk, enriched bread, etc)
      iii. Use of artificial products (artificial sweeteners)
      iv. GMOs – increases nutrition and reduces undesirable aspects (high fat, etc) while not containing artificial items, but some have concerns with safety and allergens (ex – if a vegetable contains genes from a peanut, what are the effects on those that are allergic to peanuts?) Especially problematic because of lack of labeling regulation
8. Plant and Animal Industry  
   a. Public Concerns - larger farms push out smaller farmers, growing world population, public perception of food production practices  
   b. Current Solutions –  
      i. Public awareness campaigns  
      ii. Farm buyouts – government pays small farmers to stop producing certain products that are produced more efficiently through larger farms

9. Animal Welfare  
   a. Public Concerns – public perception of food production practices related to treatment of animals  
   b. Current Solutions –  
      i. Public awareness campaigns  
      ii. Government regulations on animal treatment and production practices

10. Ethics  
   a. Public Concerns - some disagree with the slaughtering of animals for human consumption based on ethics  
   b. Current Solutions –  
      i. Vegetarianism  
      ii. GMOs – can insert animal protein genes into non-animal products, or potentially create animal tissues from cells without killing the animal

| Objective 2: | Evaluate the potential benefits and drawbacks of possible solutions to current food safety issues. |
| Content Outline: | Content for this objective is derived from that of each of the above objectives. |

### References


United States Food and Drug Administration. What we Do. Retrieved from: http://www.fda.gov/AboutFDA/WhatWeDo/default.htm

## Economic Impacts Unit Plan

<table>
<thead>
<tr>
<th>Unit Name:</th>
<th>Economic Impacts of Biotechnology on Agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Time:</td>
<td>2 Weeks</td>
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</tbody>
</table>

### Essential Questions:

1. How does the agricultural industry contribute to our economy?
2. How might GMOs impact our economy?

### Essential Question 1: How does the agricultural industry contribute to our economy?

#### Agriscience Foundations I Standards:

1. 02 – Analyze the impact of agriculture on the local, state, national, and global economy.
2. 01 – Explain the economic importance of animals and the products obtained from animals.
3. 07 – Investigate the nature and properties of food, fiber, and by-products from animals.
4. 08 – Explore career opportunities in animal science.
5. 06 – Interpret, analyze, and report data.

#### Objectives:

Students will be able to:

6. Evaluate the trustworthiness and credibility of information sources.
7. Identify agricultural products that contribute to local, state, national, and global economies, including byproducts and value-added products.
8. Analyze the economic impact of different agricultural products on different populations based on consumer trends.

#### Objective 1:

1. Evaluate the trustworthiness and credibility of information sources.

#### Content Outline:

2. Considerations in evaluation of sources:
   a. Authority of the author/publisher/speaker
      i. Who is the author?
      ii. What are the author’s credentials?
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>Educational degrees, institutional affiliation, employment experience, past writings</td>
</tr>
<tr>
<td>iii.</td>
<td>What is the author’s reputation?</td>
</tr>
<tr>
<td>1.</td>
<td>Cited in articles, books, or bibliographies on the topic</td>
</tr>
<tr>
<td>2.</td>
<td>Recommended to you by a credible person or text</td>
</tr>
<tr>
<td>iv.</td>
<td>Who is the publisher?</td>
</tr>
<tr>
<td>1.</td>
<td>Commercial, trade, institutional, or other (.edu, gov, org)</td>
</tr>
<tr>
<td>2.</td>
<td>Known for quality and/or scholar publications</td>
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<tr>
<td>3.</td>
<td>Basic values or goals</td>
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<tr>
<td>4.</td>
<td>Specialization</td>
</tr>
<tr>
<td>5.</td>
<td>Editorial board</td>
</tr>
<tr>
<td>6.</td>
<td>Blind review process</td>
</tr>
<tr>
<td>v.</td>
<td>Is the author associated with a reputable institution or organization?</td>
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<td>Organizational mission</td>
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<td>Basic values or goals</td>
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<td>b.</td>
<td>Objectivity of the author</td>
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<td>i.</td>
<td>Does the author state the goals for this publication?</td>
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<td>Inform, educate, explain</td>
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<td>Is it advocating for some particular cause?</td>
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<td>ii.</td>
<td>Does the author exhibit a particular bias?</td>
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<td>Acknowledgement of bias</td>
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<td>3.</td>
<td>Presentation of facts and arguments for both sides of a controversial issue</td>
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<td>4.</td>
<td>Language free of emotion-arousing words and biases</td>
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<td>iii.</td>
<td>Does the information appear to be valid and well-researched?</td>
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<tr>
<td>1.</td>
<td>Reasonable assumptions and conclusions</td>
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<td>Arguments and conclusions supported by evidence</td>
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<td>3.</td>
<td>Opinions not disguised as facts</td>
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<td>4.</td>
<td>Sources cited</td>
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<td>c.</td>
<td>Quality of the work</td>
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<td>i.</td>
<td>Is the information well-organized?</td>
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<td>1.</td>
<td>Logical structure</td>
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<td>2.</td>
<td>Main points clearly presented</td>
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</table>
3. Text flows well  
4. Author’s argument is not repetitive  
5. Good grammar  
6. No errors  
   ii. Are graphics appropriate and clearly presented?  
   iii. Is information complete and accurate?  
      1. Facts and results agree with your knowledge of the subject and with others in the field  
      2. Sources are documented  

d. Coverage of the work  
   i. Does the work use other sources?  
   ii. Does it support other materials you have read, or add new information?  
   iii. Have you found enough information to support your arguments?  
      1. Look for gaps in your arguments and evidence (facts, statistics, etc)  

e. Currency of the work  
   i. When was it published?  
   ii. Does the topic require current information?  
   iii. Has the source been revised or updated since its original publication?  

<table>
<thead>
<tr>
<th>Objective 2: Identify agricultural products that contribute to local, state, national, and global economies, including byproducts and value-added products.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content Outline:</td>
</tr>
<tr>
<td>1. US is #1 in the world for almonds, blueberries, cow milk, cranberries, grapefruit, maize, indigenous cattle meat, indigenous chicken meat, indigenous pig meat, indigenous turkey meat, sorghum, soybeans, strawberries, and string beans</td>
</tr>
<tr>
<td>2. US is #2 in the world for apples, cherries, game meat, hen eggs, honey, hops, lettuce, mushrooms, oranges, pistachios, spinach, tomatoes, and walnuts</td>
</tr>
<tr>
<td>3. US is #3 in the world for asparagus, avocados, carrots, grapes, hazelnuts, linseed, oats, onions, peaches, pears, green peas, raspberries, safflower seed, sugar beets, and wheat</td>
</tr>
<tr>
<td>4. US is #4 in the world for chilies and green peppers, garlic, pumpkins, tobacco leaves, and watermelon</td>
</tr>
<tr>
<td>10. US’s most important agricultural commodities (Food and Agricultural Organization of the United Nations, 2005)</td>
</tr>
<tr>
<td>a. Note – based on value according to 2001 international commodity prices to avoid exchange rate confusion</td>
</tr>
<tr>
<td>b. Maize, indigenous cattle meat, cow milk, indigenous chicken meat, soybeans, indigenous pig meat, wheat, hen eggs, tomatoes, grapes, potatoes, indigenous turkey meat, rice, lettuce, oranges, apples, sorghum, sugar beets, strawberries (these are in order from most important to least)</td>
</tr>
<tr>
<td>11. Florida’s top commodities (USDA, 2009)</td>
</tr>
<tr>
<td>a. Greenhouse/nursery, oranges, tomatoes, sugar cane, cattle/calves (in order from greatest value to least value)</td>
</tr>
<tr>
<td>b. Oranges make up 66.8% of total US value</td>
</tr>
</tbody>
</table>
c. Sugar cane makes up 46.6% of total US value

12. Florida’s top exports (USDA, 2009)
   a. Fruits (3rd top state), vegetables (5th top state), live animals/meat (24th top state), seeds (7th top state)

13. Florida’s top counties in ag. sales (USDA, 2007)
   a. Palm Beach, Miami-Dade, Hendry, Hillsborough, Polk

14. Value-added agriculture - any activity an agricultural producer performs outside of traditional commodity production to receive a higher return per unit of commodity sold. The value of the product increases per unit sold.
   a. The producer does more processing in-house
      i. A dairy makes cheese or ice cream
   b. The producer markets directly to consumers
      i. A farmer’s stand sells off the farm
   c. The producer engages in agritourism and entertainment agriculture
      i. Pick-your-own, hayrides, petting zoos
   d. Benefits – could result in more profits for producers
   e. Drawbacks – increases risk for producers, because it involves more labor/production not typically performed by the producer
   f. Examples of Value Added Businesses in Florida:
      i. Wineries using tropical fruits.
      ii. Tropical fruit ice cream and milk shakes.
      iii. Jams and jellies.
      iv. Fruit baskets.
      v. Bed and Breakfasts.
      vi. Agritourism (e.g., farm tours, festivals, picnics, catered parties).
      vii. Bird watching.
      viii. Fishing.
      ix. Spice parks.
      x. Alligator farms.
      xi. Direct sales to restaurants and retailers.
      xii. Farmers markets.
      xiii. U-pick, or pick-your-own.
      xiv. Roadside markets.

15. Agricultural by-products – items created as a result of food production
   a. Adds value to waste
   b. Examples of by-products
      i. Stem and leaf waste – (from production of vegetables, fruits, etc) can be used to produce energy (biogas or electricity), banana stem waste is used to make handmade paper (value-added byproduct)
ii. Cleaning and washing wastes – usually high moisture, low organic material. Lactic acid produced in meat packing plants from fermentation – can be used in animal feeds or as a flavoring and preserving agent

iii. Sorting waste and culls – culled apples make apple juice, others are used for animal feed, lotions, vitamins, etc.

iv. Peeling and coring wastes - orange peels can be made into citrus oil and molasses, papaya makes chewing gum, medicine, toothpaste, and meat tenderizers, others make natural sweeteners

v. Fruit pit waste – can be burned as a fuel, grapefruit seed extract can be turned into emergency water treatment product

vi. Milling waste – wheat byproducts make flour supplements, corn byproducts make corn syrup, starches, ethanol as a gas additive

vii. By-products of the Meat Industry

1. Edible by-products
   a. Unused parts – variety meat (scrap, spam, souse, loaves, etc.)
   b. Blood – component in sausage
   c. Stomach – sausage container, component of cheesemaking process
   d. Bones – gelatin in ice cream and jellied food products
   e. Fats – shortening, candies, chewing gum
   f. Intestines – sausage casings

2. Inedible by-products
   a. Hide – leather goods, upholstery
   b. Pelts – wool, ointments (lanolin)
   c. Fats – industrial oils, lubricants, animal feeds
   d. Bones – glue, fertilizer, leather preparation
   e. Cattle feet – lubricants, neatsfoot oil (leather preparations)
   f. Glands – medicines
      i. Ovaries make estrogen and progesterone
      ii. Pancreas makes insulin
   g. Lungs – pet foods
   h. Intestines – surgical sutures and condoms
   i. Liver – cortisone
   j. Spinal cord – processed into vitamin D
   k. Fetal calf blood – used for cancer and AIDS research
   l. Aorta valves – replacement in human heart valves
   m. Fetal pigs – teaching biology through dissection

**Objective 3:** Analyze the economic impact of different agricultural products on different populations based on consumer trends.
Content Outline:

4. Demographic Projections between 2002 and 2020 (USDA)
   a. Nation will become more racially diverse
   b. Proportion of population age 20-34 will decrease, while those 45-74 will increase (USDA assumes their food habits will follow those of the new age group as they age)

5. Previous trends –
   a. Increasingly, consumers have become more convenience-oriented, health conscious, and they expect food to be safe to eat, eat more processed foods, and purchase from larger supermarkets
   b. Number of local farmers’ markets has increased
   c. Demand for fresh fruits and vegetables is increasing
   d. Greater sales of environmentally friendly products and locally grown products
   e. Food budgets decreased by 2.8% between 1970 and 1No5. 2009- 9.5% of budget spent on food.
   f. Food away from home has increased (48% of food budget in 2009), over 1/3 going to fast food
     i. Average US Adult buys a restaurant snack or meal 5.8 times per week
   g. Between 1970 and 1No5, consumption of fruits, vegetables, grains, fruits, fats, oils, and sweets increased while meat and dairy has remained constant
   h. Trends in the Meat Industries – (1970-1No5)
     i. Beef consumption declined 15%, pork consumption declined 13%, chicken consumption more than doubled, turkey consumption grew 127%
        1. Due to changes in prices, income, preference, product development
     ii. Shell egg consumption decreased 37%, processed egg consumption increased 88%
        1. Due to health, taste, and convenience factors

6. USDA’s Projected Trends (2002-2020)
   a. USDA’s assumptions –
      i. As people increase in age, they will take on the eating habits of the new age group
      ii. Incomes will increase by 1% each year
   b. Growing aged population projected to impact the following food consumptions
      i. Decrease – fried potatoes, cheese, sugar, beef, poultry
      ii. Increase – other types of potatoes, fruits, fish, and eggs
   c. Increased racial diversity projected to impact the following food consumptions
      i. Decrease – dairy products, certain types of potatoes
      ii. Increase – fruits, nuts, seeds, eggs, poultry, fish, beef, poultry
   d. Food budgets will increase, with away-from-home consumption increasing more than at-home consumption
      i. At home increases – fruits, vegetables, fish, prepared foods, sugars and sweets, fish
      ii. At home decreases – beef, pork
   e. As income increases, consumers will want more quality food over quantity, including value-added products, increased diversity in products, food with greater convenience, or those that align with environmental and animal
welfare efforts
f. While overall beef consumption will decrease because of health education, income growth, aging population, and preference for poultry and fish, money spent on beef will increase because of purchasing higher quality cuts and grades, as well as semi-prepared beef meals

<table>
<thead>
<tr>
<th>Essential Question 2: How might GMOs impact our economy?</th>
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</thead>
<tbody>
<tr>
<td>Agriscience Foundations I Standards:</td>
</tr>
<tr>
<td>1.02 – Analyze the impact of agriculture on the local, state, national, and global economy.</td>
</tr>
<tr>
<td>6.01 – Explain the economic importance of animals and the products obtained from animals.</td>
</tr>
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<td>6.07 – Investigate the nature and properties of food, fiber, and by-products from animals.</td>
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<tr>
<td>6.08 – Explore career opportunities in animal science.</td>
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<td>3.06 – Interpret, analyze, and report data.</td>
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<tr>
<th>Objectives: Students will be able to:</th>
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<tr>
<td>2. Predict the economic outcomes of potential cultured meat introduction scenarios on various groups, including agricultural sectors and consumers.</td>
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<tr>
<td>Content Outline:</td>
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<tr>
<td>2. Food supply chain – businesses that collectively produce consumable items. The chain involves all aspects of food production from pre-production research to post-consumption waste disposal</td>
</tr>
<tr>
<td>a. Pre-production – research and development</td>
</tr>
<tr>
<td>b. Inputs – feed suppliers, veterinarians, breeders</td>
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<tr>
<td>c. producer – cow/calf operations, feeder operation</td>
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<tr>
<td>d. processor – slaughter, packing</td>
</tr>
<tr>
<td>e. distributor – marketers, food distributors. Sells to distributors</td>
</tr>
<tr>
<td>f. wholesaler – sells to retailers</td>
</tr>
<tr>
<td>g. retailer - supermarkets</td>
</tr>
<tr>
<td>h. consumer – people that buy the foods</td>
</tr>
<tr>
<td>i. post-consumption – waste disposal, recycling</td>
</tr>
</tbody>
</table>

| Objective 2: Predict the economic outcomes of potential cultured meat introduction scenarios on various groups, including agricultural sectors and consumers. |
### Content Outline

2. Cultured meat introduction scenarios:
   - f. Used as a non-human foodsource (pet food, animal feeds)
   - g. Introduced to malnourished countries
   - h. Introduced as a value-added product to affluent populations
   - i. Introduced to ground meat products

### References


502
| Essential Questions: | 1. How does the agricultural industry use environmental resources?  
2. Why are some public organizations concerned about the agricultural industry’s impact on environmental resources?  
3. How would the use of GMOs impact environmental resources? |

| Essential Question 1: How does the agricultural industry use environmental resources? | Agriscience Foundations I Standards:  
1.04 – Examine the role of the agricultural industry in the interaction of population, food, energy, and the environment.  
4.03 – Describe the environmental resources (soil, water, air) necessary for agriculture production.  
4.02 – Describe various ecosystems as they relate to the agriculture industry.  
4.05 – Apply Best Management Practices that enhance the natural environment.  
4.04 – Identify regulatory agencies that impact agricultural practices. |

| Objectives: | Students will be able to:  
1. Identify agricultural practices that rely on environmental resources.  
2. Explain the purposes of Best Management Practices related to environmental resources. |

| Objective 1: | Identify agricultural practices that rely on environmental resources. (1 day) |

| Content Outline: | 3. Agricultural industry accounts for 80% of nation’s water usage  
   a. Primarily for irrigation  
   b. Irrigated cropland has increased by over 40%, but water application rates have decreased by 20%. Total quantity of irrigation water applied increased 10% since 1969.  
4. Land is agriculture’s most limited resource  
   a. Farm size –  
      i. Small family farms (sales less than $10,000) make up more than half of all farms, but account for 27% of |
production

ii. In 2002, half farm sales came from 2% of US farms and 11% of farm land (increasing number of large farms)

b. Cropland has decreased in recent decades, but the nation can still produce high capacity of food and fiber

c. Three major uses are (in order) – grassland pasture and range (30.8% of nation’s land), forest-use land (29.5%) and cropland (23.3%). Urban use is 3.1% of nation’s land.

d. Grassland pasture and range – less pasture and range is needed that in the past to sustain grazing herds because of improved forage quality and productivity of land. Also, number of domestic animals (mainly sheep) has declined, requiring less pasture

e. Forest-use land – includes forestry industry and parks, wilderness areas, wildlife areas, etc.

f. Cropland – includes cropland used for crops, pasture, and idled. Corn for grain, soybeans, wheat, and hay accounted for 80% of all cropland harvested in 2002. 17 other principal crops accounted for 15%, and vegetables, fruit, nuts, melons, etc. accounted for 4.5%

g. Urban areas – remains low compared to agricultural uses, but while the US population doubled between 1945 and 2002, amount of urbanized land quadrupled.

i. Cropland changed into urban use is generally irreversible

ii. Excessive loss of cropland to urban uses could lessen the production of food and fiber and the supply of rural amenities (open space, watershed protection, rural lifestyles)

Objective 2: Explain the purposes of Best Management Practices related to environmental resources. (2 days)

Content Outline:

Land Quality BMPs – (Natural Resources Conservation Service)

7. Enhance organic matter – most important way to improve and maintain soil quality. Improves soil structure, protects soil from erosion and compaction, supports healthy habitat for soil organisms.
   a. Leave crop residues in the field
   b. Choose crop rotations that include high residue plants
   c. Use good nutrient and water management practices to grow plants with large roots and residue
   d. Grow cover crops
   e. Apply manure or compost
   f. Use low or no tillage systems
   g. Mulching

8. Avoid excessive tillage – minimizes loss or organic matter, protects soil surface with plant residue. Keeps good soil structure, reduces erosion, maintains healthy organism habitat, reduce soil compaction.

9. Manage pests and nutrients efficiently – reduces air and water pollution, reduces harm on beneficial soil organisms
   a. Test and monitor soil and pests
   b. Apply only necessary chemicals at the right time and place
   c. Use nonchemical approaches when possible

10. Prevent soil compaction – maintains air, water, and space available to plants within the soil.
11. Reduce repeated or heavy traffic, heavy equipment, traveling on wet soil
   a. Keep crop residue on surface
   b. Plant cover crops

12. Diversity cropping systems – each plant contributes a unique root structure and type of residue to the soil. Helps control pest populations, reduces weed and disease pressures (certain plants are more susceptible to certain pests), increases microorganism and organism diversity in soil.
   a. Use buffer strips (diversity at one time)
   b. Small diverse fields (diversity at one time)
   c. Crop rotation (diversity over time)

Water Conservation BMPs –
5. Developed by the USDA Natural Resources Conservation Service and EPS’s National Management Measures to Control Nonpoint Source Pollution
6. Purpose – reduce non-point sources of pollution from croplands through integrated use of best management practices
7. CORE 4 practices –
   a. Conservation tillage – leaving crop residue (plant materials from past harvests) on soil surface to reduce runoff and soil erosion, conserves soil moisture, keeps nutrients and pesticides in the field
   b. Crop nutrient management – accounting for all nutrient inputs helps ensure nutrients are available for crop needs and reduces nutrient movement off fields. Prevents buildup in soils.
   c. Pest management – various methods for keeping insects, weeds, disease, and other pests in check while protecting soil, water, and air quality
   d. Conservation buffers – provide barriers of protection by capturing pollutants that might otherwise move into surface water

8. Supplemental BMPs – aimed at benefitting production while protecting the environment
   a. Irrigation water management – reduces nonpoint source pollution of ground and surface waters from irrigation
   b. Grazing management – minimizes water quality impacts of grazing on pasture and range lands
   c. Animal feeding operations management – minimizes impacts of animal feeding operations and waste through runoff controls, waste storage, waste utilization, and nutrient management
   d. Erosion and sediment control – conserve soil and reduce sediment reaching water

Air Quality BMPs –
5. Improve ruminant animals’ production efficiency – certain substances, such as urea increases animal’s ability to digest food, so less methane is produced
   a. Supplement animals’ diet
6. Participate in methane recovery efforts – uses methane from livestock facilities to create energy
   a. AgSTAR Program- sponsored by EPA, USDA, US Dept. of Energy
7. Participate in National Clean Diesel Campaign
   a. Clean Agriculture USA Program helps farmers, ranchers, and agribusinesses reduce emissions from older engines that are in operation

Essential Question 2: Why are some public organizations concerned about the agricultural industry’s impact on environmental resources?

Agriscience Foundations I Standards:
1.04 - Examine the role of the agricultural industry in the interaction of population, food, energy, and the environment.
4.03 – Describe the environmental resources (soil, water, air) necessary for agriculture production.
4.04 – Identify regulatory agencies that impact agricultural practices.

Objectives: Students will be able to:
3. Explain the impacts of agricultural practices on the environment.
4. Compare and contrast the various benefits and environmental drawbacks related to agricultural practices.
5. Identify the role of various organizations in monitoring the agricultural industry’s impact on the environment.

Objective 1:
1. Explain the impacts of agricultural practices on the environment. (2 days)

Content Outline:
4. Water Quality
   - Agriculture is leading source of water impairments in nation’s rivers and lakes
   - 71% of US cropland is located in watersheds where pollutant concentration is above accepted levels for water-based recreation
   - Structural changes in animal agriculture between 1982 and 1987 increased levels of fecal coliform bacteria in the Great Plains, Ozarks, and Carolinas.
   - 25,823 bodies of water (streams, lakes) are impaired nationwide
   - Almost half of the wetlands in the nation have been drained during the nation’s history, most for agricultural use
   - Sediment, nutrients, pathogens, pesticides, and salts enter water sources
   - Sediment – largest contaminant of surface water, second leading pollution problem in rivers and streams. Results from soil erosion (from soil composition and agricultural production practices)
   - Nutrients – nitrogen and phosphorus are applied to cropland as crop nutrients as fertilizer and manure applications. Enter water sources through runoff and leaching. Promotes algae growth (eutrophication), which leads to lower oxygen levels, kills fish, clogs pipelines, and reduces recreations opportunities. Nitrogen pollution leading cause of water quality impairment in lakes. 9% of domestic wells during 1No3-2000 had nitrogen concentrations above EPA’s drinking water standards.
   - Pesticides – can damage freshwater and marine organisms, fisheries, drinking water, and recreations opportunities.
activities. Pesticides were found in low concentrations in 37% of groundwater sites examined in a national water quality assessment

- Salts – from excess irrigation that runs off of fields. Reduces crop yields, damages soil, increase water treatment costs
- Pathogens – bacteria are largest source of impairment in rivers and streams. From poorly treated human waste, wildlife, and animal feeding operations. Diseases can be transmitted through contact with contaminated water, or consumption of contaminated shellfish. Diseases commonly found in animals can be transmitted to humans (zoonoses)
- Enters water sources through runoff and leaching

5. Land Quality

- Disturbing the soil harms soil microbes, which help keep nutrients and water in the soil.
  - Physical disturbance – tilling
  - Chemical disturbance – misuse of inputs, like fertilizers and pesticides
- Planting the same crop over and over again robs the soil of the same nutrients repeatedly without replenishing them.
- Leavin fields bare reduces amount of nutrients in the soil
  - Causes water to leach nutrients out of soil
  - Causes erosion of soil
  - Reduces nutrient input back into soil from decomposing plant matter
  - Certain organisms begin shredding crop residues into smaller pieces, and can increase nutrient cycling by 25%. If there is no residue, there is no habitat for these organisms
- Number of U.S. farms selling hogs decreased by 94% between 1959 and 2002, while hog sales more than doubled. Similar trends have occurred among farms selling dairy products, cattle, and broilers. As livestock producers expand, they are more likely to buy feed grown elsewhere, reducing the amount of land they have available for manure application, the predominant method of disposal.
- Livestock production doesn’t pose a problem if farms have enough land to spread manure, but many livestock producers don’t spread manure to their land, or may spread more manure than crops need on the fields closest to the facility (lowers hauling cost). Some counties have more livestock manure than they do appropriate land to spread it to meet land needs.

5. Air Quality

a. Livestock farms is responsible for 18% of all greenhouse CO2 emissions, 64% of ammonia emissions, 65% of nitrous oxide, and 37% of methane worldwide
  i. Makes it difficult for states to meet Clean Air Act standards
  ii. Many compounds released by animal production cause unpleasant odors and issues with comfort, health, and production efficiency of animals and humans

1. Swine manure produces organic sulfur compounds (rotten egg smell), which can cause unconsciousness or death in high
2. Application of manure to croplands and pasture increases nitrous oxide, which is 310 more effective in trapping heat in the atmosphere than carbon dioxide. Ag. industry (both cropland and animal production) account for 72% of nitrous oxide emissions in US

3. Methane comes from ruminant animals (cattle, buffalo, sheep, goats) during digestion. Also released from liquid manure holding areas (lagoons or tanks). Livestock production accounts for 37% of total global methane emissions

Objective 2: Compare and contrast the various benefits and environmental drawbacks related to agricultural practices. (2 days)

<table>
<thead>
<tr>
<th>Content Outline: Beef Industry -</th>
</tr>
</thead>
<tbody>
<tr>
<td>iii. Feeding</td>
</tr>
<tr>
<td>1. Rotational grazing</td>
</tr>
<tr>
<td>i. 1-1.5 acres can support a cow/calf pair for an entire year</td>
</tr>
<tr>
<td>ii. In drier climates, a cow/calf pair can require up to 110 acres</td>
</tr>
<tr>
<td>2. Dry, pregnant cows get stored forages in winter (ex – hay)</td>
</tr>
<tr>
<td>3. Bulls are fed stored forages when not breeding. Require grain before, during, and after breeding to maintain body condition</td>
</tr>
<tr>
<td>4. Heifer calves get grain ration during first winter. Bred at 12-15 months old</td>
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<tr>
<td>5. All have access to free-choice salt and minerals</td>
</tr>
<tr>
<td>6. Finishing cattle (feedlot cattle) get high-grain, high-energy diet, very little forage. Results in rapid gains and increased carcass quality. Young feedlot cattle receive supplemental protein</td>
</tr>
<tr>
<td>7. Level of energy-level grain fed depends on frame of finishing cattle</td>
</tr>
<tr>
<td>8. Silages are substituted for grain in low-energy finishing diets</td>
</tr>
</tbody>
</table>

iv. Housing |
1. Mature cows need a sheltered place or windbreak |
2. Well drained to keep mud minimal |
3. Newborn calves should have access to a portable shelter if born in winter |
4. Finishing cattle can be fed in small groups indoors on a manure pack |
5. Larger feedlots are entirely outdoors, contain a windbreak for shelter and high dry place for cattle to lie |

Swine Industry – |
1. In temperate climates, can be raised outside |
2. In northern states, pigs have access to warm, dry, well-bedded shelter to keep out of cold weather |
   ii. Amount of feed must be increased if pigs are left in cold without shelter |
   iii. Growth rates slowed if temp gets below 60-65 |
3. Sows are farrowed in temperature controlled buildings |
4. Heat is more harsh on a pig than cold, so feed rate slows above 80-85 |
   a. Pigs have no sweat glands or any natural way to cool off |
b. Can cause lactating sows to lose too much body condition to be able to rebreed, boars may become infertile
c. Sprinkler systems can drip water onto pigs for cooling or outdoor facilities should have shade and
   access to a wet place to lie down

Poultry Industry –
i. Feeding
   2. Feed costs are 2/3 of total cost of producing meat from chickens
   3. Grains make up 50-80% of total feed ration
      a. Rest of feed is protein, vitamins, fats, additives, grit (often granite particles) to help chew b/c they don’t have
         teeth. Doesn’t have high need for roughages b/c doesn’t have a rumen to digest them like cattle
   4. Free choice eating because chickens will eat enough to meet energy requirements

ii. Housing
   1. Raised in confinement in an open-floor system
   2. House is cleaned and disinfected each time a flock leaves, wait one week for new flock to come in
   3. New litter is put into house for new flock
   4. Floor space per bird is increased with age (half of the house may be blocked off until chickens reach 20 weeks)
      b. Use lights 24 hours per day
   8. Temp should be controlled, starting at around 90 and slowly being decreased to 70-75 as chicks get older
      a. Chicken behavior can indicate whether they need more or less heat
         i. Huddling together and cheeping or moving away from the heaters
   9. Ventilation will prevent respiratory diseases and will reduce ammonia odor

Dairy Industry –
i. Calf Nutrition
   1. Calf is weaned immediately after receiving colostrum, then raised by humans
   2. Dairy calf is born without antibodies in the bloodstream to protect from disease (like humans are), so must have colostrum
      immediately after birth
      a. Must happen immediately because the calf’s small intestine is very porous for the first 24 hours after birth and
         readily absorbs antibodies from colostrum
      b. Frozen colostrums can be substituted if calf is removed before first meal
   3. 6-8 lbs of milk replacer are fed daily till 5-8 weeks of age
   4. High quality grain calf starter is introduced slowly at 1 week old
   5. High quality hay is introduced at 4 weeks old
   6. Weaned from milk replacer when calf-started consumption reaches 4lbs per day
   7. Milk replacer is replaced with clean water
   8. Calves’ rumens need to develop, so feeding them hay containing saliva from mature cows will provide bacteria for rumen
      development

ii. Adult Dairy Cow Nutrition
9. Small and mid size herds can reduce feed costs with intensive pasture management (closely monitored rotational grazing).
   a. Also leads to lower vet costs because of improved foot health and lower mastitis cases
   b. Can be managed seasonally so that all cows are dry in winter when grass does not grow

10. 12 weeks to 1 year – heifers are fed grain mix with feed additive (to improve feed efficiency by encouraging breakdown of methane gas bubbles in rumen) and high quality hay or silage.

11. After breeding – pregnant heifers are fed free-choice, high quality forage, maybe several lbs of grain mix to ensure proper development and provide trace minerals and vitamins

12. Lactating cows –
   a. Large quantities of milk require large amounts of high quality feed – multiple feedings per day and feeding forages before grains can increase feed intake
   b. Vitamin and mineral supplementation varies by amount of feed, which varies on lactation period
   c. Forages are tested for nutritional quality every 60 days

ii. Housing

13. Calves – individual stalls, preferably outside for improved ventilation – lowers risk of respiratory disease

14. Heifers grouped together at 8 weeks old – heifer growing barn or open fronted sheds

15. Cows were originally in tie-stall housing (stanchion barns) – remained tied in individual stalls for most of the day.
   a. Then free-stall housing to allow cow to enter and leave as they wish. Includes feed bunk for free choice eating

16. Housing often requires protective footwear or shoe disinfectant to reduce contaminants from outside sources in the barns

17. Milked in parlors, where cow comes to milkers. 8-12 are milked at one time
   a. Manure is spread on fields in liquid or solid form. Must be removed daily, either spread or stored for later; spreading rate slows if temp gets below 60-65.

Objective 3: Identify the role of various organizations in monitoring the agricultural industry’s impact on the environment. (1 day)

Content Outline:

5. USDA – Natural Resources Conservation Service
   a. Agricultural Management Assistance – provides money to ag. producers who voluntarily address issues such as water quality and management, erosion control, etc. by incorporating conservation into their farming operations

6. EPA –
   a. Safe Drinking Water Act
   b. Clean Water Act
   c. Federal Insecticide, Fungicide, and Rodenticide Act
   d. Endangered Species Act
   e. Toxic Substances Control Act
   f. Resource Conservation and Recovery Act
   g. Comprehensive Environmental Response, Compensation, and Liability Act
   h. Clean Air Act
   i. Emergency Planning and Community Right to Know Act
j. Food Quality Protection Act
k. Oil Pollution Act
l. NRCS

7. FDA – National Environmental Policy Act
   a. Required to assess environmental impacts associated with its actions, including approving food and drug products

8. States -
   a. No nationwide monitoring programs in US to calculate agricultural emissions of greenhouse gases
   b. 33 states have laws that regulate agricultural use of water and water quality
   c. Many states use standards to employ best management practices (conservation tillage, nutrient management, pesticide management, irrigation water management)

Essential Question 3: How could the use of GMOs impact environmental resources?

Agriscience Foundations I Standards:
Examine the role of the agricultural industry in the interaction of population, food, energy, and the environment.

4.03 – Describe the environmental resources (soil, water, air) necessary for agriculture production.

4.02 – Describe various ecosystems as they relate to the agriculture industry.

Objectives:
Students will be able to:
2. Describe the potential impacts of GMO use on the environment.
3. Evaluate the validity of various organizations’ claims regarding their views on the impact of GMOs on the environment.

Objective 1: Describe the potential impacts of GMO use on the environment. (1 day)

Content Outline:
3. Concerns –
   a. Risk of accidentally introducing engineered genes into wild populations
      i. Can alter wild organisms, ecosystems
   b. Persistence of the gene after the GMO has been harvested
      i. Crop residues
   c. Susceptibility of non-target organisms to the gene
      i. Insects which are not pests could be harmed
   d. Stability of the gene
      i. Does it remain as is, or does it get altered into something unwanted (ex - cancer)
      ii. Loss of biodiversity
      iii. Increased use of chemicals in agriculture
<table>
<thead>
<tr>
<th>Content Outline:</th>
<th>1. The Alliance for Better Foods -</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a. Some biotech crops are already beginning to improve the environmental performance of agriculture, and future crops may eventually make significant global contributions to the preservation of valuable forestlands in the developing world. Following are anticipated environmental benefits from food biotechnology.</td>
</tr>
</tbody>
</table>
|                  | b. **Conservation of natural resources**  
Hardier disease- and pest-resistant crops can allow greater conservation of resources by requiring less fuel, labor, water and fertilizer. For example, international researchers in Georgia and Israel are exploring ways to produce cotton that can survive in semi-arid conditions, a development that could one day lead to a savings of some 12 billion gallons of water a year. |
|                  | c. **Less land use**  
Researchers around the world are developing hardier strains of fruits, vegetables and grains that one day may be able to thrive in extreme growing conditions such as tomatoes that can flourish in high-salinity soils. Other plant varieties that can protect themselves from pests and diseases mean that growers will be able to produce more food on the same amount of land, thereby reducing pressures to clear additional acres for cultivation. According to the National Council on Food and Agricultural Policy, improved farm productivity could result in less impact on prairies, wetlands, forests and other fragile ecosystems that might otherwise be converted for agricultural purposes. |
|                  | d. **Less pesticide use**  
Biotech crops can reduce the use of agricultural chemicals such as insecticides and fungicides. Scientists have developed strains of corn and cotton that produce their own protection against specifically targeted pests, thus reducing the amount of pesticides necessary to control them. In addition, herbicide tolerant varieties of many crops have been developed. According to a study by the National Center for Food and Agricultural Policy (NCFAP), U.S. pesticide use was 45.6 million pounds lower in 2001 than it would |
have been without the use of biotech crops. The use of herbicide tolerant soybeans reduced pesticide levels by 28.7 million pounds, while herbicide tolerant cotton helped cut pesticide levels by 6.2 million pounds. Another report by NCFAP notes several studies finding that growers are achieving higher yields and attaining higher profits by planting Bt varieties of crops, due to the better pest control and decreased pest control costs they provide.

2. The Sierra Club –
   a. **SUPERWEEDS:** Genetically engineered crops were first planted in the mid 1No0s. Already, research has documented that genes producing desired characteristics in crops can confer adaptive advantages to weedy species, causing problems in valuable wild plant habitats. Research suggests that bees may be important pollen vectors over a range of distances and farm-to-farm spread of oilseed rape transgenes will be widespread. Pollen can also travel for miles in the wind and integrate its DNA into the genome of conventional plants. Genes from GEOs (genetically engineered organisms) can spread to wild plants and native species, resulting in herbicide resistant superweeds. For example, the pollen from transgenic rapeseed (canola) can blow into neighboring farms and wild areas and can easily outcross to any nearby canola plant. The herbicide resistant traits become promiscuous and transfer to weedy relatives. The traditional weed then becomes a stronger "superweed." This outcrossing has started to produce superweeds that are resistant to a wide range of herbicides. The 4/26/00 edition of New Scientist magazine reported the first officially confirmed case of its kind: weeds in Canada which became resistant to three kinds of herbicides: Roundup, Liberty and Pursuit. It only took three years for a transgenic spread of super-herbicide-resistance. This was the first documented case of gene stacking in canola occurring without deliberate human intervention. The rapid outcrossing of GEO herbicide resistant plants raises serious questions for those concerned about the emergence of weeds that do not die no matter what herbicide is applied. These superweeds may very well have a bioengineered advantage in taking over farm fields and in moving through wild areas, where they are likely to have a range of impacts on populations of wild plants and wild plant habitats.
   
   b. **BIODIVERSITY:** In the 9/18/No Worldwatch Institute report "Farmers Losing Seed Varieties Worldwide," John Tuxill wrote that in the United States more than 80% of seed varieties sold a century ago no longer are available and that the world is rapidly losing genetic diversity in crops. With development of transgenic crops, traditional varieties may dwindle even further as farmers grow a less diverse pool of crops to obtain the highest yields for commercial production. Bt (Bacillus thuringiensis) toxins are becoming ubiquitous, highly bioactive substances in agroecosystems. Bt crops are pumping out huge amounts of toxin from all tissues throughout the growing season, from germination to senescence. Most non-target herbivore insects, although not lethally affected, ingest plant tissue containing Bt protein which they can pass on to their natural enemies. There are also unanticipated effects
on non-target insects through deposition of transgenic pollen on foliage of surrounding wild vegetation. These effects herald problems for small farmers in developing countries and for organic farmers since they rely on insect pest control. For instance, loss of lady bugs and lacewings will likely result in increased crop losses. The Soil Association report (UK) on 6/22/No warned, "GM code could wipe out wildlife." Birds, for instance, might lose habitat and major food sources (both plants and insects). The spread of transgenes into the wild and the effect this will have on biodiversity may be especially severe in less developed countries and wherever native archetypal varieties of agricultural crops exist.

c. **SOIL FERTILITY:** The soil food web is crucial for plants to obtain the nutrients necessary for growth. Many crops are engineered with the Bt toxin in order to resist infestation from insects. Yet root exudates from these plants release the toxin into the soil, where it retains its activity for at least 234 days, long after its release. This stimulates major changes in soil biota that could affect nutrient cycling processes and reduce soil fertility. Monsanto's advertising campaigns try to convince people that Roundup is safe, but the facts do not support that conclusion. Independent scientific studies have shown that Roundup is toxic to earthworms, beneficial insects, birds and mammals (in addition to destroying the vegetation on which they depend for food and shelter). The Progressive Farmer on 1/3/01 reported a University of Missouri study which revealed that Roundup Ready soybeans receiving glyphosate at recommended rates had significantly higher incidence of Fusarium on roots compared with soybeans that did not receive glyphosate. Fusarium is one of the most economically important groups of fungi causing diseases on a wide variety of plants. Pat Donald, professor and director of the UM nematology lab was quoted as saying "We're concerned because SDS (sudden death syndrome) is showing up everywhere and can be devastating."

d. **EFFECTS ON NON-TARGET INSECTS:** Insects have their place in the ecosystem. Some play a major role in maintaining the equilibrium of insect populations and are important for pest control strategies. The Bt toxin has been shown to be lethal to non-target organisms such as Monarch butterflies, lacewings and ladybird beetles. The issue is broader than whether Bt toxin produced by genetically modified crops imperils beneficial insects. The real issue is that a strategy to establish expression of an insecticidal compound in large-scale crop monocultures and thus expose a homogeneous sub-ecosystem continuously to the toxin can cause irreparable damage to natural habitats forever.

e. **SUSTAINABLE AGRICULTURE AND ORGANIC FARMING THREATENED:** There are many alternative approaches that farmers can use to effectively regulate insect and weed populations, i.e. rotations, strip-cropping, biological control, cover crops, and green manure. To the extent that transgenic crops further entrench the current monoculture system, they impede farmers from using a plethora of alternative methods. The entire future of organic farming is being threatened because pollen transfers by insects and the wind from GE crops to organic farms. Cross pollination can move transgenes into the crops so that, against their intentions, farmers are growing GE crops. GE seeds can also fall off trucks and farm machinery during transport or be left in the ground, leading to the growth of stray plants. It isn't debatable if Bt resistance will develop among insects populations, the question
is how fast this will occur now that the toxins are being used in huge amounts throughout the entire growing season. Bt microbes are applied by organic farmers as a surface agent (when one is absolutely necessary) and will become ineffective as an important biological insect control tool. The problem of crop contamination not only has direct consequences for organic farmers; it also may damage our heritage of agricultural varieties, which has huge implications for populations around the world. For thousands of years, humans have selected and bred varieties adapted to unique climatic zones and regional properties. Transgenes may cause significant damage to that genetic diversity, and commercialization of a few varieties of patented seeds will also erode this vital heritage.

"Terminator" systems designed to protect seed companies' profits by ensuring that farmers can't save seed (the succeeding crop will be sterile) are a further step away from sustainable agricultural practices and respect for the diversity of our agricultural heritage.

f. GENE TRANSFER INTO GUTS OF BEES: A three year study by Professor Hans-Hinrich Kaatz at the Institute for Bee Research, University of Jena found a gene transfer from genetically engineered rapeseed to bacteria and fungi in the gut of honey bees. Beatrix Tappesser from the Ecology Institute in Freiburg was quoted as saying "This is very alarming because it shows that the crossover of genes takes place on a greater scale than we had previously assumed. The results indicate that we must assume that changes take place in the intestinal tubes of people and animals. The crossover of microorganisms takes place and people's make up in terms of microorganisms in their intestinal tract is changed. This can therefore have health consequences."

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**References**


## Animals and Biotechnology Unit Plan

<table>
<thead>
<tr>
<th>Unit Name:</th>
<th>Animals and Animal Welfare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Time:</td>
<td>3 Weeks</td>
</tr>
</tbody>
</table>

### Essential Questions:

1. How would cultured meat be created?
2. How would traditionally harvested meat compare to cultured meat in its production?
3. Why do traditionally harvested and cultured meat supporters each believe they are treating animals ethically?

### Essential Question 1: How would cultured meat be created?

<table>
<thead>
<tr>
<th>Agriscience Foundations I Standards:</th>
<th>6.03 – Illustrate correct terminologies for animal species and conditions within those species.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.02 – Categorize animals according to use, type, breed, and scientific classification.</td>
</tr>
<tr>
<td></td>
<td>6.04 – Compare the basic internal and external anatomy of animals.</td>
</tr>
<tr>
<td></td>
<td>3.07 – Investigate DNA and genetics applications in agriscience including the theory of probability.</td>
</tr>
</tbody>
</table>

### Objectives:

- Students will be able to:
  1. Explain the process of cultured meat production.
  2. Evaluate the process of cultured meat production as it addresses barriers, including taste, marbling, and its structural differences from traditionally harvested meat.

### Objective 1:

- Explain the process of cultured meat production.

### Content Outline:

1. Take small biopsy from animal
2. Extract myosatellite cells
   a. Adult stem cells responsible for muscle growth and repair
   b. Embryonic stem cells would be more beneficial, but attempts to produce embryonic stem cells from farm animals have not been successful.
   c. Some researchers prefer to plant entire biopsy in a dish instead of extracting specific cells.
      i. Would be used to produce cuts of meat (steaks, filets) instead of ground meat, since all the tissues would be present (blood vessels, fats, blood, etc)
3. Add animal-free growth serum to multiply cells
a. Available, but expensive (accounts for 90% of cultured meat costs)  
b. Used to keep protective ends of chromosomes (telomeres) from wearing down with age  
   i. Currently, myosatellite cells will only divide dozens of times before telomeres wear down  
c. Currently using traditional cell growth serum that comes from dead cows (it’s cheaper)  
   i. Also contains antibiotics and anti-fungal agents that might not be fit for human consumption  
d. Others recommend using tumor-growth-promoting genes to keep cells multiplying

4. Put myosatellite cells on a scaffold to fuse them into myofibres, which will bundle together to make up muscle  
a. Makes muscle, but weak and textureless  

5. Assemble myofibres between anchor points to allow them to flex  
a. Can also administer 10-volt shock of electricity every second to boost up protein content  
   i. Would be expensive in large industry  
b. Some use a scaffold made of chitosan (from crabs or fungi) that expand and contract with temperature variations, making it a natural fitness center for muscle strips  

6. Grind up thousands of muscle strips (can’t make a thick piece because interior cells die from lack of nutrients)  

7. Add flavoring, nutrients (like iron, which comes from blood) and vitamins (like B12, which comes from gut bacteria)

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<table>
<thead>
<tr>
<th>Objective 2: Evaluate the process of cultured meat production as it addresses barriers, including taste, marbling, and its structural differences from traditionally harvested meat.</th>
</tr>
</thead>
</table>
| **Content Outline:** Characteristics of traditionally harvested meat –  
  | 4. Beef  
  | a. Beef Quality Assurance – nationally coordinated, state implemented program that provides information to beef producers and consumers of how animal production practices and scientific knowledge can improve beef quality.  
  | b. USDA Quality Grading – includes factors that affect palatability of meat (tenderness, juiciness, and flavor). Voluntary.  
  | i. Grades –  
  | 1. Prime, choice, select, standard, commercial, utility, cutter, canner  
  | 2. Final grade calculated through knowing the appropriate degrees of marbling for each carcass maturity age.  
  | ii. Indicators -  
  | 1. Carcass maturity – physiological age of animal (not actual age)  
  | a. Indicated through bone characteristics, ossification of cartilage (more = older), color and texture of muscle (darker, coarser = older)  
  | 2. Texture – coarser = older  
  | 3. Color of lean – darker red = older  
  | 4. Amount/distribution of marbling – dispersion of fat within the lean meat.  
  | 5. Pork |
   i. Altered to PQA Plus in 2007 to reflect consumer interest in the way food animals are raised

b. Quality Indicators –
   i. Color – darker pink is preferable
   ii. Marbling – want 2-4% to give appropriate pork flavor
   iii. Water-holding capacity – amount of moisture in pork that is lost when it is cut. Lower loss is preferable; should not be higher than 2.5%

c. Pork quality can be lowered by stress. Short term stress before slaughter = pale, soft pork with decreased moisture holding capacity. Long term stress = dark, firm, dry pork

6. Poultry
   a. Agricultural Marketing Service Poultry Programs maintains US standards
   b. Quality A, B, C
   c. Quality Indicators for Ready-to-Cook Poultry –
      i. Conformation – free of deformities
      ii. Fleshing – well developed meat (breast, leg, drumstick, thigh, wing)
      iii. Fat covering – well-developed, evenly distributed
      iv. Defeathering – no feathers or hairs left on bird
      v. Exposed flesh – minimal flesh exposed from cuts, tears, and missing skin
      vi. Disjointed and broken bones, missing parts – none present
      vii. Discolorations – minimal. Large discolorations indicate the chicken was not appropriately bled out, bruising, or blood clots
      viii. Freezing defects – minimal
      ix. Backs – meat in appropriate places
   d. Additional quality indicators for specific poultry food products (roasts, breasts, drumsticks, thighs, legs)

Characteristics/Barriers of Cultured Meat –
1. Texture
2. Flavor
3. Marbling/Fat
4. Color
5. Inclusion of various nutrients

Essential Question 2: How would traditionally harvested meat compare to cultured meat in its production?
### Agriscience Foundations I Standards:

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.03</td>
<td>Identify the parts and functions of plant and animal cells.</td>
</tr>
<tr>
<td>3.04</td>
<td>Describe the phases of cell reproduction.</td>
</tr>
<tr>
<td>3.07</td>
<td>Investigate DNA and genetics applications in agriscience including the theory of probability.</td>
</tr>
</tbody>
</table>

### Objectives:

Students will be able to:

1. Describe the favorable and unfavorable anatomical characteristics of various animals related to meat production.
2. Explain the characteristics of traditionally-harvested meat and cultured meat at the cellular level.
3. Analyze differences in the reproduction processes of cultured and traditionally grown meat at the cellular level.
4. Predict trends in selective breeding that would result from the production of cultured meat.

### Objective 1:

Describe the favorable and unfavorable anatomical characteristics of various animals related to meat production.

### Content Outline:

- Beef breeds and their characteristics –
  2. Texas Longhorn – only beef breed available to US cattle producers until mid 1800s.
  i. Hardy
  ii. Lacked beefy appearance
  iii. Difficult to fatten (lean carcasses)
  8. Herefords, Shorthorns, Angus –
    a. Compared to longhorn – increased growth rate, improved mothering ability, shorter horns
    b. Bred with longhorns to give heavier muscled carcass
    c. Shorthorn –
      i. Beefy appearance
    d. Hereford –
      i. Very hardy, able to tolerate wide range of environmental conditions
    e. Angus (black and red)
      i. Most popular breed of beef cattle
      ii. Naturally polled
  9. Brahman
    a. Good for hot climates because loose hide dissipates heat well
    b. More tolerant to disease than other breeds of cattle
    c. Have been used to create other breeds – Brangus, Beefmaster, Santa Gertrudis (hardy, good maternal abilities in these three breeds)
  10. Charolais
    a. Rapid growth rate and muscling
<table>
<thead>
<tr>
<th>Breed</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chianina</td>
<td>a. Largest breed of beef cattle</td>
</tr>
<tr>
<td></td>
<td>b. Good growth rate</td>
</tr>
<tr>
<td></td>
<td>c. Lean carcasses</td>
</tr>
<tr>
<td>Limousin</td>
<td>a. Moderately framed</td>
</tr>
<tr>
<td></td>
<td>b. Heavily muscled</td>
</tr>
<tr>
<td></td>
<td>c. Rapid growth rates</td>
</tr>
<tr>
<td></td>
<td>d. Great for crossbreeding with large-framed or light-muscled cows</td>
</tr>
<tr>
<td>Maria-Anjou</td>
<td>a. Good maternal abilities</td>
</tr>
<tr>
<td></td>
<td>b. Docile temperament</td>
</tr>
<tr>
<td></td>
<td>c. Largest and heaviest framed of the French breeds</td>
</tr>
<tr>
<td>Simmental</td>
<td>a. Large</td>
</tr>
<tr>
<td></td>
<td>b. Heavily muscled</td>
</tr>
<tr>
<td></td>
<td>c. Good breeding versatility</td>
</tr>
<tr>
<td>Berkshire</td>
<td>a. Used to have short noses, but breeders have selectively bred for long noses to help animals eat from automatic self-feeders</td>
</tr>
<tr>
<td></td>
<td>b. Good mothering ability</td>
</tr>
<tr>
<td></td>
<td>c. Exceptional muscle quality (color, texture, flavor)</td>
</tr>
<tr>
<td></td>
<td>d. Can be used as maternal or paternal for crossbreeding</td>
</tr>
<tr>
<td>Chester White</td>
<td>a. Great mothering ability</td>
</tr>
<tr>
<td>Duroc</td>
<td>a. Good growth rate</td>
</tr>
<tr>
<td></td>
<td>b. Good carcass traits</td>
</tr>
<tr>
<td></td>
<td>c. Breeders have selected for extreme leanness and muscling to be used as a paternal breed</td>
</tr>
<tr>
<td>Hampshire</td>
<td>a. Used as maternal and paternal</td>
</tr>
<tr>
<td></td>
<td>b. Good muscling and leanness</td>
</tr>
<tr>
<td>Landrace</td>
<td></td>
</tr>
</tbody>
</table>
a. Large litters  
b. Exceptional milking ability  

15. Poland China  
a. Good growth rate  
b. Good muscling  
c. Hardy  

16. Spotted Swine  
a. Used as paternal breed  

17. Yorkshire  
a. Farrow and wean large, heavy litters  
b. Used as maternal breed  

18. Pietrain  
a. Very lean  
b. Heavily muscled  
c. Many carry two copies of stress gene  
d. Used to cross with other paternal breeds to produce lean, heavily muscled, crossbred sires with 0 or 1 copy of the stress gene

**Objective 2:** Explain the characteristics of traditionally-harvested meat and cultured meat at the cellular level

| Content Outline | 3. Animal cells – all cells originate from other cells. All organisms are made up of one or more cells. All cells have similar functions: a. All cells must take up nutrients from external environment  
b. All cells must excrete waste products into their external environment  
c. All cells do some kind of work (make proteins, store energy, carry oxygen, transport electrical impulse, store minerals, move)  
d. All cells must reproduce  
4. Animal cell organelles a. Cell membrane – layer that separates cell contents from external environment i. Protein “doors” allow materials to enter cell and waste/new proteins to leave cell  
b. Nucleus – brain of the cell, controls all cell activity i. Surrounded by nuclear membrane  
c. Chromosomes – small strands of genetic material that are housed in the nucleus i. Made of DNA ii. Coded pieces of DNA are genes 1. Contain blueprint for what the cell is to do and directions to replicate, as well as certain traits of the organism 2. Can be passed down to new organisms through cellular replication |
d. Cytoplasm – jelly-like substance that holds other organelles

e. Endoplasmic reticulum – network of membranes that connects cell membrane to nucleus, breaks down raw materials entering cell.
   i. Rough ER – has ribosomes, which make proteins
   ii. Smooth ER – no ribosomes

f. Mitochondria – powerhouse of the cell (manufactures ATP, which is energy)
g. Lysosomes – digest proteins
h. Golgi bodies – newly made proteins get assembled and packaged

5. Cell differentiation
a. Cells are specialized, and each type of cell has a different job
   i. Muscle cells – support body and movement
   ii. Bone cells – structure and support of body
   iii. Red blood cells – carry oxygen
   iv. Fat cells – store energy, don’t carry oxygen
   v. Some make up tissues and organs

b. Differentiated cells work together in systems
   i. Skeletal system
   1. Made of bone and cartilage
   ii. Muscular system
   1. Made of muscle tissue
   2. Attaches to skeletal system by tendons
   3. Allows skeletal system to move
   4. Blood vessels and blood cells bring energy to muscles
      a. white meat vs. dark meat – white is slower muscle with longer duration, so fewer red blood cells get to it. Dark is faster moving muscle with shorter duration – needs more oxygen, so has more red blood cells
   iii. respiratory system
      1. includes lungs
      2. supplies cells with oxygen
   iv. circulatory system
      1. heart, blood vessels
      2. takes oxygen and nutrients to cells of other tissues through red blood cells
   v. nervous system
      1. brain, spinal cord
      2. sends messages between brain and body
   vi. endocrine system
<table>
<thead>
<tr>
<th>Content Outline:</th>
<th>Cellular Reproduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Includes many specialized cells and glands</td>
<td></td>
</tr>
<tr>
<td>2. secretes substances into blood that keeps body chemically balanced</td>
<td></td>
</tr>
<tr>
<td>vii. reproductive system</td>
<td></td>
</tr>
<tr>
<td>1. ovaries, testes</td>
<td></td>
</tr>
<tr>
<td>2. enables animals to reproduce</td>
<td></td>
</tr>
</tbody>
</table>

Cultured Meat Cells

3. All muscle cells
4. No attached systems working together

Objective 3: Analyze differences in the reproduction processes of cultured and traditionally grown meat at the cellular level.

<table>
<thead>
<tr>
<th>3. Interphase – cellular growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. G1 – cell grows in size by increasing number of organelles and volume of cytoplasm</td>
</tr>
<tr>
<td>b. S – genetic material replicates so chromosomes are double (called sister chromatids)</td>
</tr>
<tr>
<td>i. Chromatids are attached to each other at centromere</td>
</tr>
<tr>
<td>c. G2 – cell manufactures organelles and prepares for cell division</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4. Mitosis – division of body cells (nonsex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Prophase – nuclear membrane disappears, sister chromatids shorten and thicken</td>
</tr>
<tr>
<td>b. Metaphase – sister chromatids line up along cell’s central axis, sisters will attach to spindle fibers at the ends of the cell</td>
</tr>
<tr>
<td>c. Anaphase – spindle fibers retract, pulling sister chromatids apart</td>
</tr>
<tr>
<td>d. Telophase – new cell membranes are formed, cytokinesis divides organelles and cytoplasm between two new cells.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5. Meiosis – division of sex cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Animals have duplicate chromosomes in body</td>
</tr>
<tr>
<td>i. Haploid is number of unique chromosomes, or homologous pairs (N)</td>
</tr>
<tr>
<td>ii. Diploid is the number of chromosomes an animal has (2N)</td>
</tr>
<tr>
<td>iii. Meiosis reduces sex cell’s diploid chromosomes to haploid</td>
</tr>
<tr>
<td>1. So that when two sex cells join up, they have 2N again, one from each parent</td>
</tr>
<tr>
<td>b. Meiosis I – results in 2 cells with pairs of chromosomes, to look like the beginning of mitosis</td>
</tr>
<tr>
<td>i. Prophase</td>
</tr>
<tr>
<td>ii. Metaphase</td>
</tr>
<tr>
<td>iii. Anaphase</td>
</tr>
</tbody>
</table>
iv. Telophase  
c. Meiosis II – splits chromosome pairs in half, so each daughter cell has half the number of chromosomes as the parent from the end of meiosis I  
i. genes in pairs are split in half with the chromosomes, so half the parent’s traits are carried down two sex cells  

Cultured Meat vs. Traditionally Grown Meat  
1. Reproduction of traditionally grown meat  
a. Mitosis used to grow animals (increase cell number and size)  
b. Meiosis used to produce animals with desired traits through selective breeding  
i. Punnet squares  
2. Reproduction of cultured meat  
a. Mitosis used to grow animal cells  
b. No meiosis – selective reproduction is done through animal selection  
i. Cultured meat will be clone of parent’s meat  

Objective 4:  
Predict trends in selective breeding that would result from the production of cultured meat.  

Content Outline:  
Contents for this objective are collectively gathered from the other content in this section.  

Essential Question 3: Why do traditionally harvested and cultured meat supporters each believe they are treating animals ethically?

Agriscience Foundations I Standards:  
6.06 – Compare and contrast animal welfare issues.

Objectives:  
Students will be able to:  
1. Compare and contrast ideals of animal welfare and animal rights.  
2. Evaluate the practices of various organizations based on their position with regard to animal rights and animal welfare.  

Objective 1:  
Compare and contrast ideals of animal welfare and animal rights.  

Content Outline:  
4. Animal Welfare – all animals should be happy, healthy, free from want, and treated humanely  
a. For animals to grow, reproduce, and perform, they must be well tended  
i. Provided with feed water, protection from parasites and disease, and protection from predators  
b. Most animal producers  
5. Animal Rights – animals should have the same rights and privileges as humans.  
a. Animals shouldn’t be used for any human benefit (food, clothing, pleasure, research)  
6. Laws related to animal welfare – not an inclusive list
<table>
<thead>
<tr>
<th></th>
<th>Animal Welfarists –</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.</td>
<td>Gentle animal handling</td>
</tr>
<tr>
<td></td>
<td>a. Reduces stress, therefore improves growth and reproduction</td>
</tr>
<tr>
<td>11.</td>
<td>Provide suitable diets and adequate water</td>
</tr>
<tr>
<td></td>
<td>a. Additives can improve animal health</td>
</tr>
<tr>
<td>12.</td>
<td>Provide living conditions that are well suited to the animals to reduce abnormal or injurious behavior</td>
</tr>
<tr>
<td></td>
<td>a. Livestock pens – keep animals away from dangers and sheltered from weather</td>
</tr>
<tr>
<td></td>
<td>b. Confining sows during gestation – eliminates competition for feed</td>
</tr>
<tr>
<td></td>
<td>c. Farrowing crates – reduces number of baby pigs crushed by sow</td>
</tr>
<tr>
<td>13.</td>
<td>Provide environments and equipment to prevent injury (penning, flooring, harnessing)</td>
</tr>
<tr>
<td></td>
<td>a. Docking piglet tails</td>
</tr>
<tr>
<td>14.</td>
<td>Provide adequate space to prevent over-crowding</td>
</tr>
</tbody>
</table>

Objective 2: Evaluate the practices of various organizations based on their position with regard to animal rights and animal welfare.
a. Overcrowding vs. temperature control
15. Improve loading and transport to reduce bruises and injuries
   a. Overcrowding and underloading both cause injuries
16. Use of appropriate techniques and equipment in slaughter process to minimize pain, fear, and distress
   a. Improves meat quality
   b. Appropriate stunning and restraining practices
17. Close attention to animals by caretakers improves potential for early diagnosis of disease and behavioral problems
18. Vaccinate for diseases that can negatively impact animals

Animal Rightists – (PETA)
8. Eat non-animal produced diet (vegan)
9. Purchase products that were not tested on animals
   a. Clothes
      i. Animal confinement
      ii. Suffering of wild trapped animals
      iii. Methods of hide harvesting (suffocation, electrocution, gas, poison)
   b. Drugs and cosmetics
      i. Poisoning of laboratory animals
      ii. Abuse of laboratory animals (experimental surgeries, etc.)
10. Attend animal-free entertainment and recreation (circuses, zoos, horse drawn carriages, animal actors, etc.)
   a. Forcing animals to perform unnatural behaviors out of fear (circuses)
   b. Use of negative reinforcement on animals being trained
   c. Animal confinement
   d. Animal boredom (zoos)
11. Adopt pets from shelters
   a. Cruel treatment of animals by owners
      i. Chained to posts
      ii. cutting ears, tails, declawing, ect.
      iii. Shock collars
      iv. Animal hoarding
   b. Pet trade/breeders
      i. Feed pet overpopulation
      ii. Inbreeding
iii. Treatment of animals like “breeding machines”
12. Spay and neuter pets
   a. Pet overcrowding
13. Use organic gardening practices
14. Lobby against animal industry practices
   a. “factory farming” practices
      i. Animal confinement
      ii. Lack of animal exercise
      iii. Separation of males, females, offspring
      iv. Use of drugs
      v. Genetic alteration to improve productivity
      vi. Animal transportation
      vii. Slaughtering practices (conscious animals during slaughtering processes)

References


APPENDIX C
STUDENT PERFORMANCE STANDARDS

SSI Content Outline

SSI: The incorporation of lab-grown meat into the nation’s food supply.

Agriscience Foundations I Standards

Overall:

- 3.08 – Evaluate advances in biotechnology that impact agriculture (e.g. transgenic crops, biological controls, etc.).
- 3.06 – Interpret, analyze, and report data.

Units:

- Food Safety (Week 1)
  - 1.04 – Examine the role of the agricultural industry in the interaction of population, food, energy, and the environment.
  - 2.03 – Evaluate the food safety responsibilities that occur along the food supply chain.
  - 6.05 – Demonstrate scientific practices in the management, health, safety, and technology of the animal agriculture industry.
  - 4.04 – Identify regulatory agencies that impact agricultural practices.
- Economic Impact (Weeks 2-3)
  - 1.02 – Analyze the impact of agriculture on the local, state, national, and global economy.
  - 6.01 – Explain the economic importance of animals and the products obtained from animals.
  - 6.07 – Investigate the nature and properties of food, fiber, and by-products from animals.
  - 6.08 – Explore career opportunities in animal science.
- Environmental Impact (Weeks 4-5)
  - 1.04 – Examine the role of the agricultural industry in the interaction of population, food, energy, and the environment.
  - 4.03 – Describe the environmental resources (soil, water, air) necessary for agriculture production.
  - 4.02 – Describe various ecosystems as they relate to the agriculture industry.
  - 4.05 – Apply Best Management Practices that enhance the natural environment
  - 4.04 – Identify regulatory agencies that impact agricultural practices.
- Animal Impact (Weeks 6-8)
  - 6.03 – Illustrate correct terminologies for animal species and conditions within those species.
  - 6.02 – Categorize animals according to use, type, breed, and scientific classification.
  - 6.04 – Compare the basic internal and external anatomy of animals.
o 3.03 – Identify the parts and functions of plant and animal cells.
o 3.04 – Describe the phases of cell reproduction.
o 3.07 – Investigate DNA and genetics applications in agriscience including the theory of probability.
o 6.06 – Compare and contrast animal welfare issues.
• The Introduction of Cultured Meat (Week 9)
  o 3.06 – Interpret, analyze, and report data
  o 3.08 – Evaluate advances in biotechnology that impact agriculture (e.g. transgenic crops, biological controls, etc.)
  o 9.03 – Identify and demonstrate ways to be an active citizen.
  o 9.05 – Demonstrate the ability to work cooperatively.
### APPENDIX D
ORDER OF LESSON PLANS

#### Design of the Study

(You can use the ✔️ down side of the list to gauge your progress through the study)

<table>
<thead>
<tr>
<th>Day #</th>
<th>Class Progress</th>
</tr>
</thead>
<tbody>
<tr>
<td>xx</td>
<td>Take the Teacher SSI Survey (done outside of class – students not involved)</td>
</tr>
</tbody>
</table>
| x     | Students take Pretest Survey  
Students take Pretests CKAg, NoS, and SR |
| 1     | Teach Introduction of Cultured Meat, Lesson 1  
Students take Pretest Arg |
| 2     | Students take Food Safety Pretest (Pre CKFS)  
Teach Food Safety, Lesson 1 |
| 3     | Teach Food Safety, Lesson 2 |
| 4     | Teach Food Safety, Lesson 3 |
| 5     | Teach Food Safety, Lesson 4  
Students take Food Safety Posttest (Post CKFS)  
Send Completed Materials to Kate |
| 6     | Students take Economic Impacts Pretest (Pre CKEc)  
Teach Economic Impacts, Lesson 1 |
| 7     | Teach Economic Impacts, Lesson 2 |
| 8     | Teach Economic Impacts, Lesson 3 |
| 9     | Teach Economic Impacts, Lesson 4 |
| 10    | Teach Economic Impacts, Lesson 5 |
| 11    | Teach Economic Impacts, Lesson 6 |
| 12    | Teach Economic Impacts, Lesson 7 |
| 13    | Teach Economic Impacts, Lesson 8 |
| 14    | Teach Economic Impacts, Lesson 9 |
| 15    | Teach Economic Impacts, Lesson 10  
Students take Economic Impacts Posttest (Post CKEc)  
Send Completed Materials to Kate |
| 16    | Teach Introduction of Cultured Meat, Lesson 2 |
| 17    | Students take Environmental Impacts Pretest (Pre CKEnv)  
Teach Environmental Impacts, Lesson 1 |
| 18    | Teach Environmental Impacts, Lesson 2 |
| 19    | Teach Environmental Impacts, Lesson 3 |
| 20    | Teach Environmental Impacts, Lesson 4 |
| 21    | Teach Environmental Impacts, Lesson 5 |
| 22    | Teach Environmental Impacts, Lesson 6 |
| 23    | Teach Environmental Impacts, Lesson 7 |
| 24    | Teach Environmental Impact, Lesson 8 |
| 25    | Teach Environmental Impacts, Lesson 9 |
| 26    | Teach Environmental Impacts, Lesson 10  
Students take Environmental Impacts Posttest (Post CKEnv) |
<table>
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<tr>
<th>Page</th>
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</thead>
<tbody>
<tr>
<td>27</td>
<td>Send Completed Materials to Kate</td>
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<tr>
<td>28</td>
<td>Teach Introduction of Cultured Meat, Lesson 3</td>
</tr>
<tr>
<td>29</td>
<td>Students take Animal Industry Pretest (Pre CKAn)</td>
</tr>
<tr>
<td>30</td>
<td>Teach Animal Industry, Lesson 1</td>
</tr>
<tr>
<td>31</td>
<td>Teach Animal Industry, Lesson 2</td>
</tr>
<tr>
<td>32</td>
<td>Teach Animal Industry, Lesson 3</td>
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<tr>
<td>33</td>
<td>Teach Animal Industry, Lesson 4</td>
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<tr>
<td>34</td>
<td>Teach Animal Industry, Lesson 5</td>
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<tr>
<td>35</td>
<td>Teach Animal Industry, Lesson 6</td>
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<tr>
<td>36</td>
<td>Teach Animal Industry, Lesson 7</td>
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<td>37</td>
<td>Teach Animal Industry, Lesson 8</td>
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<td>38</td>
<td>Teach Animal Industry, Lesson 9</td>
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<td>39</td>
<td>Teach Animal Industry, Lesson 10</td>
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<td>40</td>
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<td>41</td>
<td>Teach Animal Industry, Lesson 12</td>
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<td>42</td>
<td>Teach Animal Industry, Lesson 13</td>
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<tr>
<td>43</td>
<td>Teach Animal Industry, Lesson 14</td>
</tr>
<tr>
<td>44</td>
<td>Teach Introduction of Cultured Meat, Lesson 4</td>
</tr>
<tr>
<td>45</td>
<td>Teach Animal Industry, Lesson 5</td>
</tr>
<tr>
<td></td>
<td>Students take Animal Industry Posttest (Post CKAn)</td>
</tr>
<tr>
<td></td>
<td>Send Completed Materials to Kate</td>
</tr>
<tr>
<td>46</td>
<td>Students take Posttest Survey</td>
</tr>
<tr>
<td></td>
<td>Students take Posttests CKAg, NoS, and SR</td>
</tr>
<tr>
<td></td>
<td>Teacher takes Post Survey</td>
</tr>
<tr>
<td></td>
<td>Send Completed Materials to Kate</td>
</tr>
</tbody>
</table>
APPENDIX E
CONTENT KNOWLEDGE ASSESSMENTS

Agriscience Content

1. Goals for biotechnology’s innovations focus on ________________.
   a. Increasing food production
   b. Minimizing environmental impacts
   c. Improving human health
   d. All of the above

2. Hidden allergens can be a concern that stems from which group?
   a. environmental
   b. human health
   c. economic
   d. market sector

3. How can genetically engineered foods benefit the marketplace?
   a. provide new species with unknown viruses
   b. provide a new line of diseases
   c. provide the unexpected side effects of new food sources
   d. provide a more nutritious food

4. Zoonosis is the term that describes ________________.
   a. a disease humans can catch from plants.
   b. a disease of humans that can be transferred to animals.
   c. an animal disease that can be caught by humans.
   d. a disease humans can get from a vegetarian diet.

5. Which of the following is NOT a step in the food supply chain?
   a. packaging
   b. grading
   c. storing
   d. lumbering

6. This organization ensures that the commercial supply of meat, poultry, and egg products is safe, correctly labeled, and correctly packaged.
   a. Grain Inspection, Packers and Stockyards Administration (GIPSA)
   b. Foreign Agricultural Service (FAS)
   c. Food Safety and Inspection Service (FSIS)
   d. Animal and Plant Health Inspection Service (APHIS)

7. Golden Rice is a transgenic plant that produces _____.
   a. anticancer enzymes
   b. a substance that helps our bodies produce vitamin A
   c. a chemical that provides frost tolerance
   d. a herbicide called Roundup®
8. What is a term for animals that have had their genes changed or manipulated?
   a. clones
   b. transgenic animals
   c. naturally selected
   d. superovulated

9. In 2006, 252 million acres of GM crops were planted. What percentage of that was in the US?
   a. 12%
   b. 31%
   c. 53%
   d. 87%

10. Which of the following diseases has been linked to food recalls due to its presence in beef?
    a. H1N1
    b. Salmonella
    c. E. coli
    d. Avian Influenza

11. What is the world’s population estimated to be by 2013?
    a. 394 million
    b. 5 billion
    c. 7 billion
    d. 8.9 billion

12. Which of the following is a product that increases profit to producers through the use of waste from animal production?
    a. Value-added product
    b. By-product
    c. Sub-product
    d. Waste-product

13. What is the correct order of events in the food supply chain?
    a. retailer, distributor, grader, producer, processor, wholesaler
    b. producer, grader, processor, distributor, wholesaler, retailer
    c. processor, grader, wholesaler, producer, retailer, distributor
    d. distributor, producer, retailer, wholesaler, grader, processor

14. What is a byproduct of beef cattle?
    a. leather
    b. fur
    c. hair
    d. mohair

15. The top three commodities in the United States in terms of value are
    a. corn, beef, and milk
    b. fruits, fodder, and vegetables
    c. live animals, meat, and dairy products
    d. peanuts, sugar, and wine
16. Which of the following organizations provides data regarding a nation’s ranking in commodity production?
   a. United States Department of Agriculture
   b. University of Florida
   c. Food and Agricultural Organization of the United Nations
   d. Food and Drug Administration

17. Which of the following is a drawback of value-added agriculture?
   a. The controversial nature of value-added agriculture
   b. Results in a decrease in profit
   c. The producer takes on additional risk
   d. The producer has to advertise

18. Agricultural by-products produce which of the following:
   a. Bacon
   b. Milk
   c. Fertilizer
   d. Eggs

19. Which of the following is a demographic prediction that can impact food demand?
   a. The nation will become more racially diverse
   b. The proportion of younger people will increase
   c. The proportion of older people will decrease
   d. The nation will become less racially diverse

20. Which of the following meats doubled in consumption between 1970 and 1No5?
   a. beef
   b. chicken
   c. pork
   d. fish

21. What organization is responsible for assessing the environmental impacts associated with its approval of food products?
   a. Food and Drug Administration
   b. Environmental Protection Agency
   c. US Department of Agriculture
   d. Natural Resource Conservation Service

22. Checkoff promotions are carried out _____.
   a. for individual breeds
   b. without breed-specific identification
   c. by combining pork and beef as one initiative
   d. by combining beef and dairy as one initiative

23. What is agriculture’s most limiting resource?
   a. land
   b. water
   c. air
   d. fuel
24. Which of the following is NOT an environmental concern associated with manure?
   a. air quality
   b. water pollution
   c. soil quality
   d. biogas production

25. The agricultural industry accounts for what percent of the nation’s water usage?
   a. 15%
   b. 50%
   c. 6%
   d. 80%

26. What is the largest usage of US land?
   a. Urban use
   b. Grassland pasture
   c. Cropland
   d. Forest use

27. Which of the following is currently seen as a threat to US agriculture production?
   a. While the US population doubled between 1945 and 2002, the amount of urbanized land quadrupled.
   b. Cropland changed into urban use can be reversed, but the zoning laws make it a lengthy process.
   c. Urban land use accounts for the greatest percentage of land use in the US.
   d. Many agricultural producers prefer to live in urban areas, making urban sprawl into rural lands increase.

28. Who recommends land quality BMPs?
   a. People for the Ethical Treatment of Land
   b. US Department of Energy
   c. Food and Drug Administration
   d. Natural Resources Conservation Service

29. Which of the following is NOT a BMP related to water quality?
   a. Leave crop residue in fields
   b. Allow fertilizers to enter and enrich water sources
   c. Utilize various methods of pest management
   d. Provide conservation buffers to capture pollutants

30. Which of the following is a current environmental concern related to the production of GMOs?
   a. Could alter wild organisms and ecosystems
   b. Could reduce fertilizer applications
   c. Could negatively impact human health
   d. Could decrease urban land availability

31. ________________ are used to prevent any major/common diseases within the herd.
   a. restraint
   b. colostrums
   c. vaccinations
   d. additives
32. An example of a common permanent identification method is _____.
   a. ear tags
   b. ear notching
   c. neckchains
   d. neck straps

33. The _____ opposes the taking of wool and meat because the organization believes doing so harms animals.
   a. People for the Ethical Treatment of Animals
   b. Humane Society of the United States
   c. Florida Humane Society
   d. Farm Bureau

34. The most desired beef quality grade is _____.
   a. Select
   b. Prime
   c. Choice
   d. Standard

35. _____________ is intramuscular fat.
   a. marbling
   b. carcass age
   c. moisture content
   d. subcutaneous

36. Which is NOT a function of the cell membrane?
   a. to separate the cell contents from the external environment
   b. controls all the cell’s activity
   c. to allow raw materials to enter the cell
   d. to allow newly made proteins and waste to exit the cell

37. How many daughter cells are produced in spermatogenesis?
   a. two
   b. three
   c. four
   d. six

38. What is the match pair for the nitrogen base adenine?
   a. guanine
   b. adenine
   c. thymine
   d. cytosine

39. What breed of swine is known for a white belt, erect ears, leanness of carcass and muscling?
   a. Hampshire
   b. Yorkshire
   c. Poland China
   d. Chester White
40. What is phenotype?
   a. an organism’s physical or outward appearance
   b. the actual genetic code of an organism
   c. traits of controlled by a single pair of genes
   d. traits an organism controlled by several pairs of genes
Food Safety Test

1. Goals for biotechnology’s innovations focus on __________________.
   e. Increasing food production
   f. Minimizing environmental impacts
   g. Improving human health
   h. All of the above

2. Hidden allergens can be a concern stemming from which group?
   e. environmental
   f. human health
   g. economic
   h. market sector

3. How can biotechnology be used to improve plants?
   a. increase the nutritional value of some crops
   b. increase the amount of sunlight the plant can absorb
   c. decrease the amount of minerals the plant can take-up
   d. decrease the size of the root system

4. What is NOT an example of genetic resistance in plants?
   a. diseases
   b. flower color
   c. insects
   d. viruses

5. How can genetically engineered foods benefit the marketplace?
   e. provide new species with unknown viruses
   f. provide a new line of diseases
   g. provide the unexpected side effects of new food sources
   h. provide a more nutritious food

6. What federal agency oversees policy and regulations concerning our food supply?
   a. HSUS
   b. FDA
   c. EPA
   d. ARS
7. Zoonosis is the term that describes __________________.
   a. a disease humans can catch from plants.
   b. a disease of humans that can be transferred to other humans.
   c. an animal disease that can be caught by humans.
   d. a disease humans can get from a vegetarian diet.

8. __________ is producing food products that are safe to eat and keeping them safe for consumption.
   a. Food spoilage
   b. Food safety
   c. Grading
   d. Sanitation

9. _____ is the process of treating food to prevent or reduce spoilage.
   a. Packaging
   b. Grading
   c. Sublimation
   d. Food preservation

10. Which of the following is NOT a step in the food supply chain?
    a. packaging
    b. grading
    c. storing
    d. lumbering

11. Feeder cattle with diseases _____.
    a. must undergo correction or recovery before entering a feedlot
    b. can be put into a feedlot provided corn is fed
    c. should be harvested for dog food
    d. receive a USDA Grade of No. 1

12. This organization ensures that the commercial supply of meat, poultry, and egg products is safe, correctly labeled, and correctly packaged
    a. Grain Inspection, Packers and Stockyards Administration (GIPSA)
    b. Foreign Agricultural Service (FAS)
    c. Food Safety and Inspection Service (FSIS)
    d. Animal and Plant Health Inspection Service (APHIS)
13. What is a term for animals that have had their genes changed or manipulated?
   a. clones
   b. transgenic animals
   c. naturally selected
   d. superovulated

14. Golden Rice is a transgenic plant that produces _____.
   a. anticancer enzymes
   b. a substance that helps our bodies produce vitamin A
   c. a chemical that provides frost tolerance
   d. a herbicide called Roundup®

15. The hope for the future of agricultural biotechnology is that it may _____.
   a. address the world hunger problem
   b. become obsolete in the next decade
   c. reduce crop yield
   d. replace all traditional farming

16. Labeling of GMO products is necessary if they contain:
   a. allergens or food additives
   b. bacteria or plasmids
   c. Bt genes
   d. enhanced nutrients

17. What appears to be the greatest concerns regarding biotechnology?
   a. DNA fingerprinting
   b. genetic drift
   c. safety risks
   d. more weeds

18. In 2006, 252 million acres of GM crops were planted around the globe. Of the total GM crops planted, what percentage was in the US?
   a. 12%
   b. 31%
   c. 53%
   d. 87%

19. Which of the following diseases has been linked to food recalls due to its presence in beef?
   a. H1N1
   b. Salmonella
   c. E. coli
   d. Avian Influenza
20. Which organization is responsible for investigating consumer illnesses related to food production and consumption?
   a. Food and Drug Administration (FDA)
   b. United Stated Department of Agriculture (USDA)
   c. Animal and Plant Health Inspection Service (APHIS)
   d. Center for Disease Control (CDC)
Economic Impact Test

21. What is the world’s population estimated to be by 2013?
   a. 394 million
   b. 5 billion
   c. 7 billion
   d. 8.9 billion

22. Which of the following is a product that increases profit to producers through the use of waste from animal production?
   a. Value-added product
   b. By-product
   c. Sub-product
   d. Waste-product

23. What is the correct order of events in the food supply chain?
   a. retailer, distributor, grader, producer, processor, wholesaler
   b. producer, grader, processor, distributor, wholesaler, retailer
   c. processor, grader, wholesaler, producer, retailer, distributor
   d. distributor, producer, retailer, wholesaler, grader, processor

24. In the food supply chain, who is responsible for inserting food into containers for shipment to the processing plant?
   a. trucker
   b. retailer
   c. harvester
   d. packer

25. Which of the following is a benefit provided by the agriculture industry in the United States?
   a. The agriculture industry takes employees away from manufacturing positions.
   b. The agriculture industry tends to weaken and destabilize the central government.
   c. The agriculture industry provides the United States with imports.
   d. The basic human needs for food, clothing, and shelter are met.

26. What is one of six major areas of agriculture that is concerned with the many areas in raising animals for food consumption?
   a. livestock production
   b. forestry
   c. agricultural mechanics and technology
   d. supplies and services
27. What is a byproduct of beef cattle?
   a. leather
   b. fur
   c. hair
   d. mohair

28. _________ is the exchange of goods and services between different countries.
   a. Free trade
   b. International trade
   c. Restrictive trade
   d. Trade embargo

29. The top three commodities in the United States in terms of value are _____.
   a. corn, beef, and milk
   b. fruits, fodder, and vegetables
   c. live animals, meat, and dairy products
   d. peanuts, sugar, and wine

30. Which of the following organizations provides data regarding a nation’s ranking in commodity production?
   a. United States Department of Agriculture
   b. University of Florida
   c. Food and Agricultural Organization of the United Nations
   d. Food and Drug Administration

31. Which of the following is one of Florida’s top exports?
   a. Nursery plants
   b. Vegetables
   c. Milk
   d. Turfgrass

32. ___________ is any activity that an agricultural producer performs outside of traditional commodity production to receive a higher return per unit of commodity sold.
   a. By-products production
   b. Cultured meat production
   c. Exportation of goods
   d. Value-added agriculture
33. Which of the following is a drawback of value-added agriculture?
   a. The controversial nature of value-added agriculture
   b. Results in a decrease in profit
   c. The producer takes on additional risk
   d. The producer has to advertise

34. Agricultural by-products produce which of the following:
   a. Bacon
   b. Milk
   c. Fertilizer
   d. Eggs

35. Which of the following is a demographic prediction that can impact food demand?
   a. The nation will become more racially diverse
   b. The proportion of younger people will increase
   c. The proportion of older people will decrease
   d. The nation will become less racially diverse

36. Which of the following is not a consumer trend in the US?
   a. Greater sales of environmentally friendly products
   b. Greater sales in locally grown products
   c. Greater sales of convenience-oriented foods
   d. Greater sales of beef products

37. Which of the following meats doubled in consumption between 1970 and 1985?
   a. beef
   b. chicken
   c. pork
   d. fish

38. The USDA makes food consumption trend predictions based on which of the following assumptions?
   a. As people get older, they will make less money than they did when they were younger
   b. Income will remain constant in the upcoming years, with no raises or deductions
   c. As people get older, they will take on the eating habits of the new age group
   d. Food budgets will increase on an annual basis
39. Cultured meat production would impact which of the following aspects of the food supply chain?
   a. Producers  
   b. Consumers 
   c. Pre-production  
   d. All of the above 

40. Florida contributes over half of the US value of which of the following commodities?
   a. Sugar cane  
   b. Oranges 
   c. Watermelon 
   d. Beef cattle
Environmental Impact Test

41. The agency in the federal government that oversees food and medicine is the _____.
   a. Forest Service
   b. Natural Resources Conservation Service
   c. Food and Drug Administration
   d. Agricultural Marketing Service

42. Checkoff promotions are carried out _____.
   a. for individual breeds
   b. without breed-specific identification
   c. by combining pork and beef as one initiative
   d. by combining beef and dairy as one initiative

43. The act of ________________ a deceased animal will be most likely to eliminate the danger of water pollution.
   a. burying
   b. landfilling
   c. composting
   d. incinerating

44. Items used by the agricultural industry that occur in nature are known as ________________.
   a. environment
   b. ecology
   c. natural resources
   d. atmosphere

45. What is agriculture’s most limiting resource?
   a. land
   b. water
   c. air
   d. fuel

46. What is a gas that is emitted by decomposing organic matter, such as animal waste?
   a. Carbon monoxide
   b. fertilizer
   c. methane
   d. ethanol
47. Which of the following is NOT an environmental concern associated with manure?
   a. air quality  
   b. water pollution  
   c. soil quality  
   d. biogas production

48. Which of the following is a true statement regarding the potential of biotechnology?
   a. Biofuels from fermentation can make crops drought and salt tolerant.  
   b. Transgenic animals are being taught to speak.  
   c. Food supplies can be increased through higher yields on less land.  
   d. North America will be the only continent where transgenic crops will be grown.

49. The agricultural industry accounts for what percent of the nation’s water usage?
   a. 15%  
   b. 50%  
   c. 6%  
   d. 80%

50. What is the largest usage of US land?
   a. Urban use  
   b. Grassland pasture  
   c. Cropland  
   d. Forest use

51. Which of the following is currently seen as a threat to US agriculture production?
   a. While the US population doubled between 1945 and 2002, the amount of urbanized land quadrupled.  
   b. Cropland changed into urban use can be reversed, but the zoning laws make it a lengthy process.  
   c. Urban land use accounts for the greatest percentage of land use in the US.  
   d. Many agricultural producers prefer to live in urban areas, making urban sprawl into rural lands increase.

52. What are BMPs?
   a. Biotechnology and Marketing Products  
   b. Breakdown Manure Pads  
   c. Best Management Practices  
   d. Borrowed Money Protection
53. What organization or agency recommends the use of land quality BMPs?
   a. People for the Ethical Treatment of Land
   b. US Department of Energy
   c. Food and Drug Administration
   d. Natural Resources Conservation Service

54. Which of the following is NOT a BMP related to water quality?
   a. Leave crop residue in fields
   b. Allow fertilizers to enter and enrich water sources
   c. Utilize various methods of pest management
   d. Provide conservation buffers to capture pollutants

55. Which of the following water pollutants is a result of soil erosion?
   a. Sediment
   b. Pesticides
   c. Salts
   d. Pathogens

56. Why are nutrients considered a water pollutant?
   a. They can alter the taste of drinking water, making people less likely to drink it
   b. They come from human waste, so they can transfer diseases through water
   c. They damage crop yields
   d. They promote algae growth, leading to lower oxygen levels in water

57. Which of the following is an example of a physical disturbance that impacts land quality?
   a. Over fertilizing
   b. Using pesticides
   c. Tilling
   d. Growing same crop repeatedly

58. Due to the large amounts of carbon dioxide, ammonia, nitrous oxide, and methane emissions produced by livestock farms, some states have a difficult time meeting standards of which Act?
   a. Safe Drinking Water Act
   b. Clean Air Act
   c. Toxic Substances Control Act
   d. Food Quality Protection Act
59. What organization is responsible for assessing the environmental impacts associated with its approval of food products?
   a. Food and Drug Administration
   b. Environmental Protection Agency
   c. US Department of Agriculture
   d. Natural Resource Conservation Service

60. Which of the following is a current environmental concern related to the production of GMOs?
   a. Could alter wild organisms and ecosystems
   b. Could reduce fertilizer applications
   c. Could negatively impact human health
   d. Could decrease urban land availability
Animal Science Test

61. Which of the following is NOT a good health management practice?
   a. purchasing your animals from a reputable person
   b. keeping animals in weather they will not tolerate
   c. monitoring animals daily
   d. separating sick animals from healthy animals

62. What is an infection of the milk-secreting glands?
   a. heat
   b. mammary illness
   c. mastitis
   d. estrus

63. What is the process of removing the testicles from the male animals so they cannot breed?
   a. docking
   b. dehorning
   c. banding
   d. castrating

64. What method of identification is commonly used in pigs?
   a. microchips
   b. ear notching
   c. neck chains
   d. branding

65. ________________ are used to prevent any major/common diseases within the herd.
   a. restraint
   b. colostrums
   c. vaccinations
   d. additives

66. A _____ is used to prevent disease from entering a livestock site.
   a. non-slip floor
   b. antibacterial hand gel
   c. foot-bath
   d. steel toed boots

67. An example of a common permanent identification method is _____.
   a. ear tags
   b. ear notching
   c. neckchains
   d. neck straps
68. The _____ opposes the harvesting of wool and meat from animals because the organization believes doing so harms animals.
   a. People for the Ethical Treatment of Animals
   b. Humane Society of the United States
   c. Society for the Prevention of Cruelty to Animals
   d. Farm Bureau

69. The most desired beef quality grade is _____.
   a. Select
   b. Prime
   c. Choice
   d. Standard

70. For animal transport, _____ is necessary.
   a. adequate ventilation
   b. appropriate bedding
   c. a safety check of the vehicle
   d. All of the above

71. _______________ is intramuscular fat.
   a. marbling
   b. carcass age
   c. moisture content
   d. subcutaneous

72. Preventive health measures (e.g., administering recommended vaccines) may _____ by minimizing the number of animals with poor health.
   a. lower input costs
   b. increase productivity
   c. minimize death loss
   d. All of the above

73. High-quality food has become the norm in the United States due in part to a uniform set of terms established by the United States Department of Agriculture (USDA) known as _________________.
   a. grades
   b. weights
   c. measures
   d. regulations
74. Which is NOT a function of the cell membrane?
   a. to separate the cell contents from the external environment
   b. controls all the cell’s activity
   c. to allow raw materials to enter the cell
   d. to allow newly made proteins and waste to exit the cell

75. What is the sequential process of somatic cell division?
   a. mitosis
   b. spermatogenesis
   c. oogenesis
   d. cell growth

76. What are chromatids?
   a. thread-like fibers
   b. strands of identical DNA that join to form a chromosome
   c. daughter cells
   d. the division of the cytoplasm

77. How many daughter cells are produced in spermatogenesis?
   a. two
   b. three
   c. four
   d. six

78. What is a chromosome?
   a. part of a cell that contains energy
   b. part of a cell that contains the genetic material
   c. cell site for the production of proteins
   d. cell site for the production of hormones

79. What is the match pair for the nitrogen base adenine?
   a. guanine
   b. adenine
   c. thymine
   d. cytosine

80. What is a genotype?
   a. the physical appearance
   b. technique for predicting number of offspring
   c. traits controlled by several pairs of genes
   d. the actual genetic code
81. What is the proper name of the meat that is produced by swine?
   a. beef
   b. mutton
   c. pork
   d. lamb

82. What is the act of providing animals with surroundings that meet their needs while under human control?
   a. animal rights
   b. animal welfare
   c. controlled environment
   d. biotechnology

83. What act was passed in 1966 to regulate the treatment of animals in research, exhibition, transport, and commerce and their treatment by dealers?
   a. animal welfare act
   b. health research extension act
   c. laboratory animal welfare act
   d. economic research act

84. What breed of beef cattle are white to a light straw color, can either be polled or horned and are known for their heavy muscling?
   a. Angus
   b. Charolais
   c. Hereford
   d. Shorthorn

85. What breed of swine is known for a white belt, erect ears, leanness of carcass and muscling?
   a. Hampshire
   b. Yorkshire
   c. Poland China
   d. Chester White

86. What term is used to describe the genotype when two haploid gametes containing the same allele of a gene come together during fertilization?
   a. dominant
   b. heterozygous
   c. homozygous
   d. recessive
87. What is a phenotype?
   a. an organism’s physical or outward appearance
   b. the actual genetic code of an organism
   c. traits controlled by a single pair of genes
   d. traits controlled by several pairs of genes

88. What is a matrix that provides a technique for predicting genotype?
   a. Bakewell’s equation
   b. Mendel’s law
   c. Punnett square
   d. quantitative table

89. What is the term describing superior traits resulting from the mating of two animals from different genetic lines?
   a. purebred
   b. hybrid vigor
   c. inbreeding
   d. crossbreeding

90. Which is the MOST important purpose for using genetic modification in animals?
   a. to develop animals totally new and unique to agriculture
   b. to enhance the appearance of agriculturally important animals
   c. to improve genetic diversity of food-producing animals
   d. to increase production of food-producing animals
1a. Suppose you are given two clay balls of equal size and shape. The two clay balls also weigh the same. One ball is flattened into a pancake-shaped piece. Which of these statements is correct?

   a) The pancake-shaped piece weighs more than the ball
   b) The two pieces still weigh the same
   c) The ball weighs more than the pancake-shaped piece

1b. because

   a) The flattened piece covers a larger area.
   b) The ball pushes down more on one spot.
   c) When something is flattened it loses weight.
   d) Clay has not been added or taken away.
   e) When something is flattened it gains weight.

2a. To the right are drawings of two cylinders filled to the same level with water. The cylinders are identical in size and shape.

   Also shown at the right are two marbles, one glass and one steel. The marbles are the same size but the steel one is much heavier than the glass one.

   When the glass marble is put into Cylinder 1, it sinks to the bottom and the water level rises to the 6th mark. If we put the steel marble into Cylinder 2, the water will rise

   a) To the same level as it did in Cylinder 1
   b) To a higher level than it did in Cylinder 1
   c) To a lower level than it did in Cylinder 1

2b. because

   a) The steel marble will sink faster.
   b) The marbles are made of different materials.
   c) The steel marble is heavier than the glass marble.
   d) The glass marble creates less pressure.
   e) The marbles are the same size.
3a. To the right are drawings of a wide and narrow cylinder. The cylinders have equally spaced marks on them. Water is poured into the wide cylinder up to the 4th mark (see A). This water rises to the 6th mark when poured into the narrow cylinder (see B).

Both cylinders are emptied (not shown) and water is poured into the wide cylinder up to the 6th mark. How high would this water rise if it were poured into the empty narrow cylinder?

- a) To 8
- b) To 9
- c) To 10
- d) 12
- e) None of these answers is correct

3b. because

- a) The answer cannot be determined with the information given.
- b) It went up 2 more before, so it will go up 2 more again.
- c) It goes up 3 in the narrow for every 2 in the wide.
- d) The second cylinder is narrower.
- e) One must actually pour the water and observe to find out.

4a. Water is now poured into the narrow cylinder (described in Item 5 above) up to the 11th mark. How high would this water rise if it were poured into the empty wide cylinder?

- a) To 9
- b) To 8
- c) To 7 ½
- d) To 7 1/3
- e) None of these answers is correct

4b. because

- a) The ratios must stay the same.
- b) One must actually pour the water and observe to find out.
- c) The answer cannot be determined with the information given.
- d) It was 2 less before so it will be 2 less again.
- e) You subtract 2 from the wide for every 3 from the narrow.
5a. At the right are drawings of three strings hanging from a bar. The three strings have metal weights attached to their ends. String 1 and String 3 are the same length. String 2 is shorter. A 10-unit weight is attached to the end of String 1. A 10-unit weight is also attached to the end of String 2. A 5-unit weight is attached to the end of String 3. The strings (and attached weights) can be swung back and forth and the time it takes to make a swing can be timed.

Suppose you want to find out whether the length of the string has an effect on the time it takes to swing back and forth. Which strings would you use to find out?

a) Only one string
b) All three strings
c) 2 and 3
d) 1 and 3
e) 1 and 2

5b. because

a) You must use the longest strings.
b) You must compare strings with both light and heavy weights.
c) Only the lengths differ.
d) To make all possible comparisons.
e) The weights differ.

6a. Twenty fruit flies are placed in each of four glass tubes. The tubes are sealed. Tubes I and II are partially covered with black paper; Tubes III and IV are not covered. The tubes are placed as shown. Then they are exposed to red light for five minutes. The number of flies in the uncovered part of each tube is shown in the drawing.

This experiment shows that flies respond to (respond means move to or away from):

a) Red light but not gravity
b) Gravity but not red light
c) Both red light and gravity
d) Neither red light nor gravity

6b. because

a) Most flies are in the upper end of Tube III but spread about evenly in Tube II.
b) Most flies did not go to the bottom of Tubes I and III.
c) The flies need light to see and must fly against gravity.
d) The majority of the flies are in the upper ends and in the lighted ends of the tubes.
e) Some flies are in both ends of each tube.
7a. In a second experiment, a different kind of fly and blue light was used. The results are shown in the drawing:

![Diagram of tubes with blue light and various entries and exits indicating fly behavior.]

*These data show that flies respond to* (respond means move to or away from):

a) Blue light but not gravity  
b) Gravity but not blue light  
c) Both blue light and gravity  
d) Neither blue light nor gravity

7b. *because*

a) Some flies are in both ends of each tube.  
b) The flies need light to see and must fly against gravity.  
c) The flies are spread about evenly in Tube IV and in the upper end of Tube III.  
d) Most flies are in the lighted end of Tube II but do not go down in Tubes I and III.  
e) Most flies are in the upper end of Tube I and the lighted end of Tube II.

8a. Six square pieces of wood are put into a cloth bag and mixed about. The six pieces are identical in size and shape, however, three pieces are red and three are yellow. Suppose someone reaches into the bag (without looking) and pulls out one piece. *What are the chances that the piece is red?*

a) 1 chance out of 6  
b) 1 chance out of 3  
c) 1 chance out of 2  
d) 1 chance out of 1  
e) Cannot be determined

8b. *because*

a) 3 out of 6 pieces are red.  
b) There is no way to tell which piece will be picked.  
c) Only 1 piece of the 6 in the bag is picked.  
d) All 6 pieces are identical in size and shape.  
e) Only 1 red piece can be picked out of the 3 red pieces.
9a. Three red square pieces of wood, four yellow square pieces, and five blue square pieces are put into a cloth bag. Four red round pieces, two yellow round pieces, and three blue round pieces are also put into the bag. All the pieces are then mixed about. Suppose someone reaches into the bag (without looking and without feeling for a particular shape piece) and pulls out one piece.

What are the chances that the piece is a red round or blue round piece?

- a) Cannot be determined
- b) 1 chance out of 3
- c) 1 chance out of 21
- d) 15 chances out of 21
- e) 1 chance out of 2

9b. because

- a) 1 of the 2 shapes is round.
- b) 15 of the 21 pieces are red or blue.
- c) There is no way to tell which piece will be picked.
- d) Only 1 of the 21 pieces is picked out of the bag.
- e) 1 of every 3 pieces is a red or blue round piece.

10a. Farmer Brown was observing the mice that live in his field. He discovered that all of the mice were either fat or thin. Also, all of them had either black tails or white tails. This made him wonder if there might be a link between the size of the mice and the color of their tails. So he captured all of the mice in one part of his field and observed them. Below are the mice that he captured.

Do you think there is a link between the size of the mice and the color of their tails?

- a) Appears to be a link
- b) Appears not to be a link
- c) Cannot make a reasonable guess

10b. because

- a) There are some of each kind of mouse.
- b) There may be a genetic link between mouse size and tail color.
- c) There were not enough mice captured.
- d) Most of the fat mice have black tails while most of the thin mice have white tails.
- e) As the mice grew fatter, their tails became darker.
11a. The figure below at the left shows a drinking glass and a burning birthday candle stuck in a small piece of clay standing in a pan of water. When the glass is turned upside down, put over the candle, and placed in the water, the candle quickly goes out and water rushes up into the glass (as shown at the right).

This observation raises an interesting question: Why does the water rush up into the glass?

Here is a possible explanation. The flame converts oxygen into carbon dioxide. Because oxygen does not dissolve rapidly into water but carbon dioxide does, the newly formed carbon dioxide dissolves rapidly into the water, lowering the air pressure inside the glass.

Suppose you have the materials mentioned above plus some matches and some dry ice (dry ice is frozen carbon dioxide). Using some or all of the materials, how could you test this possible explanation?

- a) Saturate the water with carbon dioxide and redo the experiment noting the amount of water rise.
- b) The water rises because oxygen is consumed, so redo the experiment in exactly the same way to show water rise due to oxygen loss.
- c) Conduct a controlled experiment varying only the number of candles to see if that makes a difference.
- d) Suction is responsible for the water rise, so put a balloon over the top of an open-ended cylinder and place the cylinder over the candle.
- e) Redo the experiment, but make sure it is controlled by holding all independent variables constant, then measure the amount of water rise.

11b. What result of your test (mentioned in #21 above) would show that your explanation is probably wrong?

- a) The water rises to the same level as it did before
- b) The water rises less than it did before
- c) The balloon expands out
- d) The balloon is sucked in

12a. A student put a drop of blood on a microscope slide and then looked at the blood under a microscope. As you can see in the diagram below, the magnified red blood cells look like little round balls. After adding a few drops of salt water to the drop of blood, the student noticed that the cells appeared to become smaller.
This observation raises an interesting question: Why do the red blood cells appear smaller?

Here are two possible explanations: I. Salt ions (Na\(^+\) and Cl\(^-\)) push on the cell membranes and make the cells appear smaller. II. Water molecules are attracted to the salt ions so the water molecules move out of the cells and leave the cells smaller.

To test these explanations, the student used some salt water, a very accurate weighing device, and some water-filled plastic bags, and assumed the plastic behaves just like red-blood-cell membranes. The experiment involved carefully weighing a water-filled bag, placing it in a salt solution for ten minutes, and then reweighing the bag.

What result of the experiment would best show that explanation I is probably wrong?

- a) The bag loses weight
- b) The bag weighs the same
- c) The bag appears smaller

12b. What result of the experiment would best show that explanation II is probably wrong?

- a) The bag loses weight
- b) The bag weighs the same
- c) The bag appears smaller
APPENDIX G
ARGUMENTATION QUALITY RUBRIC

Argumentation Scoring Rubric (Sadler & Fowler, 2006)

# of Justifications:

<table>
<thead>
<tr>
<th>Score</th>
<th>Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Justification</td>
<td>Fails to provide a justification in support of position</td>
</tr>
<tr>
<td>1</td>
<td>Justification with no Grounds</td>
<td>Provides justification of position but fails to support justification with any grounds (data, warrants, or backings)</td>
</tr>
<tr>
<td>2</td>
<td>Justification with Simple Grounds</td>
<td>Justification is supported relatively simply by a single ground</td>
</tr>
<tr>
<td>3</td>
<td>Justification with Elaborated Grounds</td>
<td>Justification is supported by elaborate and well-supported grounds</td>
</tr>
<tr>
<td>4</td>
<td>Justification with Elaborated Grounds and Counterposition</td>
<td>Justification is supported by elaborate grounds and recognizes positions or evidence contradictory to their own</td>
</tr>
</tbody>
</table>
APPENDIX H
ARGUMENTATION SCENARIO

Argumentation Pretest

Name _____________________________

Grade level _______________________

Teacher ___________________________

School code _______________________

Scenario: Current research timelines state that lab grown meat could be offered to consumers in grocery stores as early as 2012. As a food consumer, your decisions to purchase or not purchase certain products can impact the production of certain foods. Below, develop a thorough argument that responds to the following question:

Would you purchase or consume cultured meat offered by grocery stores? Why or why not?
1. When two different theories arise to explain the same phenomenon (ex – fossils of dinosaurs), will scientists accept the two theories at the same time?

<table>
<thead>
<tr>
<th>Option</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Uncertain</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Yes, because scientists still cannot objectively tell which one is better; therefore, they will accept both tentatively.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>B. Yes, because the two theories may provide explanations from different perspectives, there is no right or wrong.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>C. No, because scientists tend to accept the theory they are more familiar with.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>D. No, because scientists tend to accept the simpler theories and avoid complex theories.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>E. No, the academic status of each theory proposer will influence scientists’ acceptance of the theory.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>F. No, scientists tend to accept new theories which deviate less from the contemporary core scientific theory.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>G. No, scientists use intuition to make judgments.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>H. No, because there is only one truth, scientists will not accept any theory before distinguishing which is best</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
2. Scientific investigations are influenced by socio-cultural values (ex – current trends, values).

A. Yes, socio-cultural values influence the direction and topics of scientific investigations.

B. Yes, because scientists participating in scientific investigations are influenced by socio-cultural values.

C. No, scientists with good training will remain value-free when carrying out research.

D. No, because science requires objectivity, which is contrary to the subjective socio-cultural values.

3. When scientists are conducting scientific research, will they use their imagination?

A. Yes, imagination is the main source of innovation.

B. Yes, scientists use their imagination more or less in scientific research.

C. No, imagination is not consistent with the logical principles of science.

D. No, imagination may become a means for a scientist to prove his point at all costs.

E. No, imagination lacks reliability.
4. Even if the scientific investigations are carried out correctly, the theory proposed can still be disproved in the future.

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<th>Scientific research will face revolutionary change, and the old theory will be replaced.</th>
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<tr>
<td>A</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Uncertain</td>
<td>Agree</td>
<td>Strongly Agree</td>
</tr>
</tbody>
</table>

|   | Scientific advances cannot be made in a short time. It is through a cumulative process; therefore, the old theory is preserved. |   |   |   |   |
|B  | Strongly Disagree | Disagree | Uncertain | Agree | Strongly Agree |

|   | With the accumulation of research data and information, the theory will evolve more accurately and completely, not being disproved. |   |   |   |   |
|C  | Strongly Disagree | Disagree | Uncertain | Agree | Strongly Agree |

5. Scientists’ observations are influenced by personal beliefs (ex – personal experiences, presumptions); therefore, two scientists may not make the same observations for the same experiment.

|   | Observations will be different, because different beliefs lead to different expectations influencing the observation. |   |   |   |   |
|A  | Strongly Disagree | Disagree | Uncertain | Agree | Strongly Agree |

|   | Observations will be the same, because the scientists trained in the same field hold similar ideas. |   |   |   |   |
|B  | Strongly Disagree | Disagree | Uncertain | Agree | Strongly Agree |

|   | Observations will be the same, because through scientific training scientists can abandon personal values to conduct objective observations. |   |   |   |   |
|C  | Strongly Disagree | Disagree | Uncertain | Agree | Strongly Agree |

|   | Observations will be the same, because observations are exactly what we see and nothing more. Facts are facts. Interpretations may be different from one person to another, but observations should be the same. |   |   |   |   |
|D  | Strongly Disagree | Disagree | Uncertain | Agree | Strongly Agree |

|   | Observations will be the same. Although subjectivity cannot be completely avoided in observation, scientists use different methods to verify the results and improve objectivity. |   |   |   |   |
|E  | Strongly Disagree | Disagree | Uncertain | Agree | Strongly Agree |
6. Most scientists follow the universal scientific method, step-by-step, to do their research (ex – state a hypothesis, design an experiment, collect data, and draw conclusions).

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<tr>
<td>A.</td>
<td>The scientific method ensures valid, clear, logical and accurate results. Thus, most scientists follow the universal method in research.</td>
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<td>B.</td>
<td>Most scientists use the scientific method because it is a logical procedure.</td>
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<td>C.</td>
<td>The scientific method is useful in most instances, but it does not ensure results; therefore, scientists invent new methods.</td>
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<td>D.</td>
<td>There is no so-called the scientific method. Scientists use any methods to obtain results.</td>
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<td>E.</td>
<td>There is no fixed scientific method; scientific knowledge could be accidentally discovered.</td>
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<tr>
<td>E.</td>
<td>No matter how the results are obtained, scientists use the scientific method to verify it.</td>
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APPENDIX J
TEACHER CONSENT FORM

Dear Agriscience Foundations Teacher,

Your Agriscience Foundations class has been selected to participate in a research study 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 students today, but will benefit future students.

You will be asked to deliver nine weeks of developed instructional plans to your Agriscience Foundations class. In addition to these classroom lessons and assessments, you will be asked to deliver several assessments to your students before and after the unit. The assessments will measure students’ scientific reasoning, views of the nature of science, and argumentation skills. You will also be asked to administer a survey to your students before and after the unit to measure their exposure to socioscientific issues and their perceptions of the classroom lessons in this study. Lastly, you will be asked to complete a survey regarding your perceptions of a socioscientific issue at the beginning of the study, and another survey at the end of the study which gathers information about your perceptions of the lessons. Your identity and the identities of your students will be kept confidential to the extent allowable by law.

Your participation is voluntary and you may withdraw your consent to participate at anytime without penalty. 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 Kate Shoulders (katewoggs@ufl.edu) or Dr. Brian Myers (bmyers@ufl.edu) at (352) 273-2614. Questions or concerns about your child’s rights as a research participant may be directed to the UFRIRB Office, University of Florida, Box 112250, Gainesville, FL, 32611, (352) 392-0433.

I have read the procedures described above. I, ____________________________________________, voluntarily give consent to participate in this study. I have received a copy of this description.

Signature: ___________________________ Date: ___________________________
Dear Parent or Guardian,

Your child’s Agriscience Foundations class has been selected to participate in a research study 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 an assessment measuring scientific reasoning assessment, views of the nature of science, and argumentation, taking approximately 45 minutes at the beginning and end of the study. Your child will also be asked to complete a survey at the beginning of the study asking about their reading, television, and internet habits, and one at the end of the study asking about their perceptions of the instruction they experienced. Your child’s identity will be kept confidential to the extent allowed by law. Also, participation in this study will not affect their grades in the course.

Your participation is voluntary and you may withdraw your consent for your child to participate at anytime without penalty. 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 Kate Shoulders (katewoggs@ufl.edu) or Dr. Brian Myers (bmmyers@ufl.edu) at (352) 273-2614. 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 procedures described above. I voluntarily give consent for my child, ________________________________ , to participate in this study. I have received a copy of this description.

Parent/Guardian: ___________________________  Date: ___________________________

Approved by
University of Florida
Institutional Review Board 02
Protocol # 2011-IRB-0718
For Use Through: 07-13-2012
Informed Assent for Students

Protocol Title: Investigation of teaching methods’ effect on student content knowledge, scientific reasoning, views of the nature of science, and argumentation skills.

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

Purpose of the research study:
The primary purpose of this study is measure the effect of certain teaching methods on student learning.

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

Time required:
Lesson plans have been developed to take 9 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:
Kate Shoulders, Graduate Student, Department of Agricultural Education and Communications, P.O. Box 110540, P: (352) 273-2614, katewoops@ufl.edu
or
Brian Myers, PhD, Assistant Professor, Department of Agricultural Education and Communications, P.O. Box 110540, P: (352)392-0502, bmyers@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, P: (352) 392-0433

Agreement:
I have read the procedure described above. I voluntarily agree to participate in the procedure and I have received a copy of this description.

Participant: ___________________________ Date: ___________________________

Principal Investigator: ___________________________ Date: 7-25-11

Approved by
University of Florida
Institutional Review Board 02
Protocol #: 2011-U-0718
For Use Through: 07-13-2012
LIST OF REFERENCES


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BIOGRAPHICAL SKETCH

Catherine W. Shoulders was born and raised in the suburbs of Philadelphia, Pennsylvania. Her interest in agriculture began as a girl scout, when a trip to go horseback riding started a lifelong passion for training horses. Although her high school did not offer agricultural education, Catherine spent most of her nonacademic time learning how to ride, train, and care for horses at Gwyn Meadows Farm.

After graduating from the Honors Program at North Penn High School in 2001, Catherine pursued her undergraduate degree in Equine Science at Murray State University, in Murray, Kentucky, where she was a student of the Honors Program. During her junior year, Catherine switched majors to Agricultural Education. She became a McNair Scholar, and completed an undergraduate thesis focusing on the standardized test scores of agricultural education students in Kentucky. Catherine's research was accepted to be presented at the Southern Region American Association of Agricultural Educators annual conference in 2005, where she first began to consider pursuing a Ph.D. Graduating summa cum laude with an Honors Diploma, Catherine was named the 2005 Outstanding Senior in Agricultural Education.

Following the completion of her B.S. degree in 2005, Catherine accepted a teaching position at Graves County High School, where she was the school's first female agriculture teacher. During her four years as an agriculture teacher, Catherine taught multiple courses related to animal science and agribiology, as well as served on the school's curriculum committee. Catherine also secured funds to build a livestock facility, and designed, oversaw construction, and managed the facility during her final year teaching.
While employed as an agriculture teacher, Catherine received both her M.S. in agriculture and her M.A. in administration. Upon completion of her M.A., she enrolled in the graduate program at the University of Florida. She began a fellowship in the university’s Agricultural Education and Communication Department in August of 2009 under the advisement of Dr. Brian E. Myers. Through her fellowship responsibilities, Catherine taught numerous courses for the department, supervised teaching interns, and conducted qualitative and quantitative research related to the integration of science in agricultural education. Her work with the department led to her receiving several regional research awards, as well as college, university, and national teaching awards.