A DESCRIPTION AND EXPLORATION OF HOW FOUR TEACHERS INTERPRET AND PRACTICE BSAA CURRICULUM

BY

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DISSERTATION

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ABSTRACT

This study explored secondary agriculture education as practiced by four teachers and sought to examine and describe how they interpreted and practiced the Biological Science Applications in Agriculture (BSAA) curriculum. The following questions were examined: (a) What does BSAA teaching look like in practice? (b) How do teachers perceive their teaching of BSAA curriculum? (c) What role does inquiry play in BSAA classes? (d) Do teachers' practice and perceptions align? (e) How are science and agriculture blended in BSAA? On what do teachers base this decision?

This study used a qualitative research design. The theoretical framework included two perspectives: the Theory of Planned Behavior (Ajzen, 1991) and the Sociocultural Model of Embedded Belief Systems. A phenomenological approach was used to explore, describe and analyze the lived experiences of the four teachers. Data collection procedures included semi-structured interviews and observations of participants' practice. Data were coded and analyzed using Saldana's (2009) codes theory model for qualitative inquiry, and Glaser & Strauss's (1965) constant comparative method.

The findings from my research described participants' implementation of the BSAA curriculum. The findings indicated (a) these teachers used a variety of instructional approaches ranging from traditional lecture to inquiry-based learning, and (b) while they blended science and agriculture content in their instruction no teacher taught one to the exclusion of the other. (c) Teachers said they valued BSAA as a context in which to teach science, and (d) all four teachers professed adequate knowledge of science content to feel comfortable teaching BSAA, although their self-described understanding of the use of inquiry ranged from uncertain to proficient.

Thank you; Faith, for your trust and support; Mom and Dad, for your steadfast love and backing; Shannon, Stephanie, and Sara, for being there for me through thick and thin; Margery, for your patience, guidance, and giving me a chance; and cherished relatives, especially my grandparents and U.B.

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CHAPTER ONE: INTRODUCTION

This qualitative study sought to describe and explore how a group of agriculture teachers that teach biological science applications in agriculture, a class designed to integrate science content into an agriculture context, interpreted and practiced the BSAA curriculum. Although there has been research that discusses agriculture teachers' experiences with teaching science in the context of agriculture, and research that supports teaching science in the context of agriculture, little has been written on the topic from a qualitative perspective and none related specifically to the BSAA course. The lack of qualitative research in agriculture may be because the typical researcher in agriculture education was trained to conduct empirical research, and may not be familiar with qualitative research conceptual frameworks (Dooley, 2007). My qualitative study may serve as a window into the classrooms of four agriculture teachers and offer insight into experiences that existing quantitative research has not provided.

The conceptual framework of my study is based on The Sociocultural Model of Embedded Belief Systems (Jones & Carter, 2007; Hutchins, 2009). This model references the teacher's sociocultural context as the environment in which the teacher operates. Environmental factors can include the school or community culture, peers and administrators, and students and stakeholders. Feedback from these factors, filtered by the teacher's perceptual filter, may lead to modifications of the teacher's belief system.

The second framework that guided my study was The Theory of Planned Behavior (Ajzen, 1991). This theory seeks to describe an individual's intention to perform a given behavior as based on a series of influences. Intent indicates how hard people will try, or how much effort they plan to exert in order to perform said behavior. It is the balance between various motivations, such as time, resources, or skills, which determines a person's behavior.

The research I am conducting on teachers' conceptions of and experiences with blending science and agriculture is occurring at a good time; secondary agriculture programs are being pushed to integrate more academic content in their curriculum.

Purpose of the Study and Research Questions

Using the theoretical frames of The Sociocultural Model theory and The Theory of Planned Behavior with the questions raised during my pilot study provided the basis for my research questions: 1. What does BSAA teaching look like in practice? 2. How do teachers perceive their teaching of BSAA curriculum? 3. What role does inquiry play in BSAA classes? 4. Do teachers' practice and perceptions align? 5. How are science and agriculture blended in BSAA? On what do teachers base this decision?

Significance of the Study

My research is unique in that the overwhelming majority of empirical studies that examine blending of agriculture and science are from a quantitative viewpoint. The existing data provides us an overview of the situation faced by many of today's practicing agriculture teachers; whether they have the confidence and competence to use inquiry-based instruction to integrate science content into their agriculture curriculum. The existing data does not describe how teachers blend science and agriculture via inquiry, situating it within the context of their classrooms nor does not address whether teachers' perceptions of their practice aligns with their actual practice. Coming from a qualitative perspective, my research reveals insights and rich descriptions that helps the reader to understand the nuances of the BSAA teachers' experiences.

Background

The idea to explore the tensions teachers' feel related to BSAA instruction crystalized after I finished a related pilot study. I learned that while the teachers in my study said they valued BSAA as a curriculum, there were tensions they felt related to lack of resources, training, and instructional time.

Researcher's Stance

I am passionate about this topic in large part because of my personal background and experiences. As a former secondary school teacher of eight years, I was curious about what it was about my horticulture classes that was conducive to teaching and learning. I started my teaching career in urban Columbus, Ohio. My students had chosen at the end of their sophomore year to pursue a two-year vocational horticulture pathway with me because they either had the desire to pursue a career in the green industry or they had not met with a great deal of success in a traditional "main stream" curriculum. What I came to realize during my first few years of teaching was that although my students would excel in the authentic, individualized instruction they received in my program, they would struggle in the more regimented "worksheets and rows of desks" environment of their academic courses. A number of my students would earn an "A" in my class, only to earn failing marks in their science classes. I wondered why this was the case.

One explanation I considered was my manner of teaching. My philosophy was trying whatever I could to help my students make connections with the curriculum. I would use lecture, labs, field trips, presentations, guest speakers, games, songs, role-play, student-led instruction, and research projects. I was very open to my students sharing their understanding of the material in any way that made sense to them, which might take the form of a song, oral presentation, drawings, peer instruction, demonstration, or building their answer out of clay or Lego.

In hindsight, I realize that perhaps my students' success could be explained by the fact that everything we studied was in the context of horticulture. Due to the nature of my curriculum I had great latitude in my instruction. Topics of instruction could include language arts, social studies, art, math, or science. An example of language arts includes helping students to learn the Latin names of plants and taxonomic nomenclature, working on the meanings and origins of different root words and deducing the meanings of new words from context and previous experience. Social studies were included in the history and origins of agriculture and horticulture, and the geography or where our plants come from and where different flora would grow well and thrive. The arts could be found in my classroom in a multitude of ways, including the use of color theory and the elements of design, when we arranged flowers, or designed and landscaped the grounds of our school. Math content was commonly included in my instruction, which took the form of talking about how satellites are used to provide triangulation for our GPS sensor we used for surveying the landscape, or estimating the cubic feet of soil needed and the costs of a landscape install, or the retail price of a floral arrangement.

Science was probably the most ubiquitous academic subject integrated in my curriculum. Throughout the year my students were in the greenhouse growing and experimenting with plants. Sometimes they measured the effects of different levels of fertilizer, sunlight, or available water on plant growth. At other times they dissected plants and seeds and discussed the various morphologies and functions of parts. Amongst the myriad other topics, we talked about why bees see in the ultraviolet, why greenhouses should be made out of glass, not fiberglass, why spraying an anti-desiccant on a cut tree helps it to stay green longer, and why adding salt to soil prevents nutrient uptake in plants.

The integration of academic content into agriculture has since been interesting to me. Several years ago, when I learned of the existence of the BSAA curriculum, I was reminded of my questions related to what it was about my horticulture classes that was conducive to teaching and learning. It was by reflecting on these experiences that I was spurred in my investigation of BSAA instruction.

Outline of the Chapters

In the next chapter I provide a review of pertinent literature relevant to my study: education reform, science integration in agriculture, teachers, and scientific inquiry. Chapter two ends with a discussion of gaps in existing research and operational definitions of my study.

In chapter three I describe and justify my research design, describe my methodology, and introduce my participants. I also describe the setting of my data collection and my data collection and analysis procedures.

In chapter four I present the findings of my data related to inquiry-based instruction. Devoted primarily to my observations of the four teacher's classroom instruction, the chapter presents transcripts and descriptions of 15 episodes, and is divided into four main sections, each dedicated to one of my participants. The chapter ends with a summary of my observations of their respective classroom practices.

In chapter five, I present findings associated with my interviews of, and conversations with my participants. The chapter is divided into four sections; the first entails teachers' perceptions of the BSAA class and whether science or agriculture content is of more importance. The second section examines the teacher training and science background. The third talks about teachers' informal experiences with science and scientific inquiry, and the fourth section relates to teachers' conceptions of their practice and understanding of scientific inquiry (SI).

In chapter six I examine similarities and incongruities between what the teachers told me in our conversations and what I observed during their practice. My examination is accomplished by discussing how my findings align with my research questions. Next, I present my conclusions and discuss their significance and potential implications. Finally I consider future plans for the research of my dissertation.

CHAPTER TWO: REVIEW OF LITERATURE

My review of literature focuses on the following areas that provide necessary background information for understanding the context of my study and the significance of my research question. These are: education reform, science integration in agriculture, teachers, and scientific inquiry.

History of Educational Reform

"The educational foundations of our society are being eroded by a rising tide of mediocrity" (NCEE, 1983). In 1983, President Ronald Reagan's National Commission on Excellence in Education issued a report entitled *A Nation at Risk: The Imperative for Educational Reform*. This report presented evidence of a downward trend and academic underachievement in the US. The solution proposed by educators and school reformers to the reported problems was to strengthen academics and better prepare students for the world of work. This reform climate of the 1980s impacted agriculture education.

Legislation.

Perkins I - 1984. In response to *A Nation At Risk* (*ANAR*), the Carl D. Perkins Vocational Education Act of 1984 (Perkins I) was created, replacing the Vocational Education Act of 1963 (Gordon, 2008). Aligned with the ideals of *ANAR*, Perkins I was created "to expand, improve, modernize, and develop quality vocational education programs in order to meet the needs of the nation's existing and future workforce for marketable skills, and to improve productivity and promote economic growth" (Scott & Sarkees-Wircenski, 2004).

Perkins II - 1990. Perkins II was passed in 1990 by the U.S. Congress in large part to increase accountability. Vocational education programs were required to establish standards of success by which the programs could be measured. These standards were crafted at the local and state levels and approved at the federal level for each state. In addition to developing vocational skills, Perkins II marked a shift in vocational education policy because it emphasized academics as well (Threeton, 2007).

Perkins III - 1998. While officially repealing the Smith-Hughes Act, Perkins III introduced common core performance indicators to measure the success of students in obtaining and keeping a job in their vocational field following program participation (Friedle, 2011). Perkins III maintained the focus on academic integration and required greater accountability of the states, by requiring them to report on a common set of core indicators, including measures of student academic and vocational/technical achievement (Friedel, 2011). States were required to make annual progress toward improved performance, and poor measures of student achievement performance were linked to monetary disincentives (Levesque Lauen, Teitelbaum, Alt, & Librera, 2000).

No Child Left Behind – 2001. In another move to increase accountability and educational standards, the No Child Left Behind Act (NCLB), a reauthorization of the Elementary and Secondary Education Act of 1965, was passed in 2001. Crafted with the belief that local government had failed students, it was thought that federal intervention was necessary to remedy complacency in the face of continually failing schools (Mizell, 2003).

NCLB was designed to hold all students to the same academic standards. The legislation did not assert a national achievement standard; standards were set by each individual state. In order to meet these new standards, the federal government required "stronger school accountability, more stringent qualifications for teachers, and an emphasis on programs and strategies with demonstrated effectiveness" (Reeves, 2003). Accountability was enforced through yearly standardized testing to measure student performance. Schools that met or exceeded performance benchmarks received additional funds while schools that did not meet their goals faced decreased funding or punishments (Martin, Fritzsche, & Ball, 2006). These sanctions ranged from the school being compelled to develop a two-year improvement plan or being forced to offer free tutoring to struggling students, to contracting out teaching to private corporations or to closing of the school altogether. This practice of using standardized testing to measure student performance against mandated benchmarks became known as "high stakes testing," a term coined in the 1980s.

Perkins IV – 2006. Under Perkins IV, career and technical education (CTE) was to be more-closely integrated with academics and articulation between secondary programs and post-secondary programs was improved. Stakes were high; for example, if after two consecutive years a state failed to meet 90% of any core indicator, the U.S. Secretary of Education could withhold up to 15% of that state's Perkins IV allocation. If states opted out of the program they were denied the opportunity to apply for funds under any other program administered by the U.S. Department of Education.

Changes to CTE. When it was first introduced, the NCLB act appeared to be legislation that would have little effect on career and technical education, since NCLB does not measure students' progress and scores in their vocational content areas. However, CTE does not stand alone, and as courses offering embedded math and science credits to secondary students have been created, the requirements of NCLB have been increasingly felt in schools with CTE programs (Kymes, 2004). While technically exempt from NCLB requirements, CTE programs recruit and draw from the populations of students in their districts and secondary schools. This dependence means that CTE programs must do what they can to increase math and science scores to remain attractive and viable options for students.

This accountability has resulted in increased academic rigor in CTE. *ANAR* recommended that high school graduates minimally should take four years of English, three years each of math, science, and social studies, and one-half year of computer science (Levesque et al., 2000). The percentage of graduates meeting these goals in 1982 was a dismal 13%. The percentage of graduates meeting these goals had increased to 50% by 1994. A similar increase in magnitude (from 5% to 22%) was demonstrated by secondary students participating in vocational education classes (Levesque et al., 2000). An argument could be made that these increases were due, at least in part, to policy shifts such as *ANAR* and the Perkins legislation. Agriculture teachers who have started integrating science into the curriculum have experienced "an increase in enrollment because of greater science integration" (Myers & Thompson, 2009).

Science Integration in Agriculture

Because of the educational reforms discussed above, agriculture educators have been encouraged to integrate more science content into their curriculum (Martin et al., 2006). In the context of lagging student academic achievement nationwide, changing demographics such as the decrease of families whose income is derived from farming, and in a competition to stay relevant, agriscience programs have created courses specifically designed to teach science in the context of agriculture.

New Agriculture Education Classes Created

Answering the call of the Perkins legislation, many states and entities set about developing new and/or revised courses that emphasized agriscience. The State of Illinois became the early leader in this effort by releasing the Biological Science Applications in Agriculture and Physical Science Applications in Agriculture (BSAA and PSAA) courses from 1990-1994 (Moss & Porter, 2002). Other states modified or adopted this curriculum for their own use:

> These courses (BSAA and PSAA) are designed to reinforce and extend students' understanding of science by associating scientific principles and concepts with relevant applications in agriculture. They are valuable preparations for further education and increase the relevance of science through the applied setting of agriculture by enhancing literacy in science and the scientific process. (Moss & Porter, 2002)

Today, this agriscience curriculum created in Illinois has been used by agriculture teachers in every state (Osborne, 2000). Myers and Thompson (2009) wrote that agriscience educators need to create "buy-in" from the educational profession to integrate science and math into the curriculum. BSAA, and similar science-based agriscience courses, do just that, enabling secondary students enrolled in agriculture courses to receive laboratory science credit (Dyer & Osborne, 1999).

Challenges Teachers Face with Integration

Two factors that may determine if science integration in agriculture classes will be successful are the teacher's confidence in their teaching skills, and competence with the curriculum content.

Confidence to integrate science into their curriculum. Although teachers have concerns with adopting this sort of curriculum change, many educators are confident they can make this transition smoothly. The numbers vary from study to study, but many feel they are prepared. Washburn and Myers (2010) reported that 79.9% of respondents reported that they felt prepared to teach integrated biological sciences and physical science concepts. Thompson and Balschweid (1999) found that 72.4% of teachers he studied strongly agreed they felt prepared to teach integrated biology and 64.7% of those surveyed felt prepared to teach integrated physics. Having the confidence to teach science content was also the focus of investigations of 210 agriscience teachers in Oregon conducted by Thompson and Balschweid (1999) and a 2009 study by Scales et al. of 210 Missouri agriculture education teachers. In both surveys of instructors the studies found teachers said they were “confident” in their abilities to teach science content. Scales et al. (2009) adds that the practicing teachers they studied said that if instructors are going to be expected to teach science concepts, “there must be an effective and focused in-service program designed to increase their knowledge about science and to expose them to the methods used to teach this content.” This leads to the next topic of preparation.

Competence to integrate science in their curriculum. The notion of increasing teacher knowledge of science content and the methods of teaching science is well addressed in the literature. Gill and Dooley (2009) stated that “One of the most prominent barriers that teachers believe are hindering the increase in integration are the lack of core subject competence among teachers in agricultural education and the lack of integrated curriculum.” Myers and Thompson (2009) said that their research had found that teachers responded that they would stress continuous professional development and pedagogy training on how to integrate academic content into the classroom. In other words, in-service training appears to be the best solution for practicing agriscience teachers.

Preservice teachers. The general consensus in the literature is that current agricultural educators believe that teacher preparation programs should incorporate instruction that focuses on math, science, and reading integration into their programs to better prepare preservice teachers to do academic integration. There is a great deal of agriculture education literature on the notion of improving teacher preparation in this way (Balschweid & Thompson, 2002; Washburn & Myers, 2010; Thoron & Myers, 2010). Washburn and Myers (2010) also reported that nearly 80% of teachers in their survey agreed that cooperating teachers should model for teacher interns how to integrate science.

Scientific Inquiry

Agriculture as a Context to Practice Inquiry

The National Research Council says that students learning about authentic questions via inquiry-based learning is "the central strategy for teaching science" (NRC, 1996, Standards, paragraph 8). Very similar to inquiry-based learning, problem-based learning is alike "in intent, process, and anticipated learning outcomes" (Parr & Edwards, 2004), and is widely accepted and recommended by agriculture educators as an effective method of teaching agriculture (Olowa, 2009).

Challenges Teachers Face with Scientific Inquiry

Similar to the challenges of integrating science into agriculture instruction, limitations of knowledge and inexperience can be barriers for teachers attempting to use an inquiry/problem-based learning approach (Glasgow, 1997; Hodson, 1988). Barriers to implementation of inquiry-based instruction often stem from teacher experience, especially those new to the profession (Crawford, 1999). Less-experienced teachers may not have sufficient knowledge of content, students, management, and pedagogy, which can combine to increase the challenges of using inquiry in their classroom (Athanases, Bennet, & Wahleithner, 2013).

Due to the nature of inquiry being student focused, with the teacher guiding in support, it is important that teachers be trained and comfortable with their roles and the roles of their students (Ball & Cobern, 1996). Similar findings were presented in a study of agriculture teachers in which participants were asked about the challenges they faced using inquiry instruction. Among the themes presented was teachers' having to become accustomed to the changing of their role from knowledge disseminator to that of facilitator (Thoron, Myers, & Abrams, 2011).

Limitations of time may be a limiting factor as well. Inquiry-based instruction can take a great deal more time (Cochran-Smith & Lytle, 2009; 1999; Shoulders & Myers, 2011) than traditional instruction. If a teacher feels constrained by a shortage of time the result may be rushed lessons and skimmed-over content.

Gaps in Research

In the challenges mentioned above I perceive interesting contradictions. While the responses of the surveyed teachers were generally positive regarding integrating science and agriculture content, and a majority of those surveyed said they were confident in their ability to integrate science and agriculture, teacher competence to teach the science content was questioned. Secondly while it is acknowledged that scientific inquiry is a powerful method of teaching science content, teacher unfamiliarity with inquiry-based instruction remains a barrier to its use.

The survey data provides us an overview of the situation faced by many of today's practicing agriculture teachers; whether they have the confidence and competence to use inquiry-based instruction to integrate science content into their agriculture curriculum. The existing data does not describe how teachers blend science and agriculture via inquiry, situating it within the context of their classrooms nor does not address whether teachers' perceptions of their practice aligns with their actual practice.

I am seeking deep and rich descriptions of the experiences, beliefs, and values of my participants. I hope my research will yield insights and meaningful explanations to these phenomena that the existing data could not.

Operational Definitions

Agriscience: Agriscience is applied agriculture classes (animal science, horticulture, etc.) that use and emphasize science to explain, support, and describe agriculture.

BSAA: Standing for biological science applications in agriculture, BSAA is a course designed to teach science content in the context of agriculture in secondary classrooms.

FFA: An acronym that formerly was used as shorthand for "Future Farmers of America," it is now an acronym that is used in place "The National FFA Organization." The National FFA Organization is a youth organization centered on middle and secondary schools, with membership exceeding 600,000. It is primarily a career and technical organization that instills lifelong skills into those involved.

Problem-Based Learning (PBL): A student-centered pedagogy in which students learn about topics via experiences in solving open-ended problems. The students are challenged to identify what they know and don't know and are guided in their explorations by the teacher, who serves as a facilitator, not a disseminator of knowledge.

SAE: A supervised agricultural experience (SAE) is a prerequisite to obtaining an FFA chapter degree in the National FFA Organization and is a form of experiential learning. It is a student-led project that can range from raising livestock to growing field crops at home, school, or elsewhere.

STEM: An acronym for science, technology, engineering, and mathematics education, STEM is an interdisciplinary approach to learning in which academic content is taught in real-world contexts to help students to make connections between school and their lived experiences.

Scientific Inquiry: According to the NRC (1996):

> Inquiry involves making observations, posing questions, examining sources of

information to see what is already known, designing investigations, using tools to gather, analyze, and interpret data, proposing answers, explanations, and predictions, and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (p. 23)

Scientific literacy: The knowledge and understanding of scientific concepts and processes necessary to people for making personal decisions and participating in societal affairs.

CHAPTER THREE: METHODOLOGY

The purpose of my qualitative study is to describe and explore how a sample of BSAA teachers interpreted and practiced the BSAA curriculum. In my first chapter I introduced the research questions and rationale for my study. I discussed research relevant to my study in chapter two. In this chapter I describe my research methods, introduce my participants, and describe the setting of my data collection. I also describe my data collection and analysis procedures.

I will focus on describing, exploring, characterizing, and interpreting practices of BSAA teachers (Denzin & Lincoln 2000). My study will use qualitative methods of data collection, such as classroom observations and the use of open-ended interviews (Creswell, 2007), observations, and document analysis, to analyze and identify patterns and themes that address the following research questions:

1. What does BSAA teaching look like in practice?
2. How do teachers perceive their teaching of BSAA curriculum?
3. What role does inquiry play in BSAA classes?
4. Do teachers' practice and perceptions align?
5. How are science and agriculture blended in BSAA? On what do teachers base this decision?

Research Design

My research design is qualitative in nature. I entered into my exploration not expecting to uncover specific answers to a proposed hypothesis, but instead hoped to better understand agriculture teachers' experiences and sentiments about the BSAA curriculum. If I had to categorize the methodological approach of my study I would say my inquiry stems from a phenomenological tradition (Gall, Gall, & Borg, 2003). This approach seeks to explore, make sense of, and describe to others the lived experiences of participants (Patton, 2002). As I observed these teachers in their classrooms, their natural settings, I sought to interpret and find meaning in both the phenomena of the teacher in instruction, and the meanings they shared with me that they formed from their own experiences teaching BSAA.

Qualitative methodology is appropriate for my study because I seek to describe and understand the experiences and beliefs of my participants. The data I collected were not experimentally generated, examined, or measured in terms of quantity, intensity, or frequency (Denzin & Lincoln, 2000; Punch, 1998).

Pilot Study

I conducted a pilot study to investigate BSAA teachers', administrators', and guidance counselors' opinions of the BSAA class. I visited four BSAA teachers and three administrators and guidance counselors. From my interviews and time visiting with them, several themes emerged. The first theme related to what all three groups considered to be the benefits of teaching science in the context of agriculture. The second related to teacher confidence and competence teaching science content. A third theme concerned the challenges of limited instruction time and resources. These findings piqued my interest and steered me toward what would become my research topic.

Setting and Participants

Description of the BSAA curriculum.

The BSAA curriculum consists of two major instructional sections; plant science and animal science. The following is an overview of the course from the University of Illinois' Agriculture education website (Meyers, 2012):

> BSAA is a course that reinforces and extends students' understanding of science and the scientific process by associating scientific principles and concepts with relevant applications in agriculture. Students will examine specific agricultural applications and processes and the underlying science principles explaining or controlling those applications. This course will use numerous laboratory exercises and experiments as the major tool of instruction. Students will also be required to develop two unique science experiments and run those experiments during the semester. Grading will mainly be based on laboratory reports over experiments conducted in the class but tests, quizzes and homework assignments will also be given. Topics of instruction will include the major phases of plant growth and management in agriculture, the specific biological science concepts that govern management decisions, genetics, biotechnology, growth, development, reproduction, aquaculture, and processing of animal products. The FFA organization and Supervised Agricultural Experience Programs will also be covered in this course. (p. 1)

At the time I conducted my data collection three of the teachers were teaching units in the plant science section, and one was teaching from the animal science section. A description of the units of instruction taught during my interactions with the participants is located in Appendix A.

Overall, the unit I observed Mr. Black teaching related to plant sciences. I observed two lessons, over a period of six days. The first dealt with physiological processes related to photosynthesis; the second was related to germination. In the time I observed Mr. Green, he was teaching in the plant sciences unit. The lessons dealt with plant science and genetics. He also taught a lesson on ice cream, as a reward to his class, which was drawn from the food science unit but was taught during his plant science unit. During the time of my visits with Mrs. Flowers, her lessons were drawn from the plant science and scientific research units, and revolved around the topics of plant nutrition, the nitrogen cycle, and designing scientific research in agriculture. Mr. Wayne was teaching from the animal science unit, on the topic of animal reproduction during my visits. His content included reproductive structures, comparative anatomy, physiology, and sperm viability/motility.

Teacher and School Information.

Table 1 provides a summary of information related to the teacher and the context in which they teach.

Table 1

Teacher and School Information

Teacher Information					School Information				
Teacher	Age/Gender	Years Teaching Secondary Education	Degrees and Certificates	Childhood	School Enrollment*	Agriculture Enrollment	BSAA Enrollment	Student Ethnicity District*/Class**	Free and Reduced Lunch*
Mr. Green	30/Male	8	BA in agriculture education Science education certification	Produce farm from 6th grade onward	750	91	22	51% White/ 72% White	61%
Mr. Black	44/Male	22	BS/MS in agriculture education Science certification	100 acre farm until 5th grade, hobby farm afterwards	450	140	9	94% White/ 89% White	28%
Mrs. Flowers	38/Female	16	BS in agriculture education Biology certification	1000+ acre grain and hog farm from 2nd grade onward	335	85	24	96% White/ 94% White	10%
Mr. Wayne	34/Male	12	BA agriculture education CASE certification***	1000 acre grain farm	751	98	22	87% White/ 88% White	33%

*Data from Illinois Report Card 2013-2014

**Teacher identified

***Agriculture Science (Animal and Plant), Natural Resources and Ecology

Participant Selection

I was interested in recruiting mid-career participants that were known for their science teaching. I met with a teacher educator to inquire if she would recommend any participants that would be good to talk to and she recommended three. I used email to contact potential participants and explained the purpose and methods of the study. Of those three, one consented to participate. I met with that teacher and asked him if he could recommend teachers that were effective teachers of BSAA. I was given the names of three teachers, of which one agreed to participate. That teacher also provided me with names and from this snowball sampling method, starting with key informants and asking them to recommend others, I was able to accumulate four participants.

The four participants in my study were established secondary BSAA teachers, identified in this study with the pseudonyms Mr. Black, Mr. Wayne, Mr. Green, and Mrs. Flowers. No two participants worked in the same school district. They ranged from 8 to 22 years teaching experience (see Table 1) and were located at four different secondary schools in a region approximately 40 miles by 40 miles square.

The final selection criteria for my participants were:

1. Teachers of BSAA
2. Established teachers
3. Recommended by a teacher educator or their peers

All research participants signed a consent form with the understanding that data collected would be kept confidential, and that at any time they could withdraw from my study.

Data were collected during a period from July, 2014 through December, 2014. I conducted three of the teachers' first semi-structured interviews prior to the 2014 school year and one in September. I conducted observations of the teachers' instruction in the following time frames: Mr. Green and Mrs. Flowers, between September 12 and October 26, Mr. Black from November 4 to November 25, and Mr. Wayne from November 20 to December 16. On days I would observe a teacher I would typically arrive 5-10 minutes early to prepare and briefly chat with the teacher if time allowed. I would stay for the duration of the class, which varied by day and teacher. Mr. Wayne's class ran 50 minutes three days a week and 1.5 hours one day a week, Mrs. Flowers' and Mr. Black's classes lasted 50 minutes five days a week., and Mr. Green's class was 50 min three days a week and 1.25 hours once a week. This schedule was sometimes superseded by school assemblies, student testing, holidays, etc.

Following my analysis of the interviews, the teachers were asked to participate in a second round of ad hoc interviews. These short discussions were conducted when the teacher was available. The purpose of this second interview included clarification of the intended meaning of previous interview responses and the posing of new questions that emerged from the analysis of previous questions and observations.

Data Collection Methods

As stated above, data was collected via teacher interviews and classroom observations. I also kept an audio record of my reflections immediately following the data collection. Following is an in-depth description of these data collection methods.

Interviews. The use of interviews was an essential data collection strategy. To better learn about each participant's unique experiences and their conceptions of BSAA, the interview was used to obtain descriptions of their youth, past experiences and, current teaching setting. I based my semi-structured interview protocol (Patton, 2002) on the Sociocultural Model of Embedded Belief System (Jones & Carter, 2007).

The interview inquired about participants' backgrounds, agriculture program, experiences and perceptions with BSAA, thoughts about the science component of BSAA, and if they make use of inquiry-based instruction. My questions reflected themes that emerged from my pilot study and the components of the Sociocultural Model of Embedded Belief System.

My questions aligned well with the constructs of the model (see Figure 2). For example, in this model an individual teacher's belief system is comprised of different components. One component is "Beliefs and values about: Inquiry-based instruction, Course goals, Science, Agriculture." My question #2, "How do teachers perceive their teaching of BSAA curriculum," explores these issues.

Another component, "Instructional Practices," is addressed by my question #1, "What does BSAA teaching look like in practice?" The teacher's perception of environmental responses to their practice, situated in their specific sociocultural context, may lead to modification to their belief system. This environmental feedback can also influence curricular decisions teachers make, as seen in my question #5, "How are science and agriculture blended in BSAA? On what do teachers base this decision?"

My question #4 is addressed when I compare interview data (related to components of their belief system such as "Attitudes towards BSAA Implementation" and their "Knowledge and Motivation") with observations of their practice. Question #3 seeks to understand the role inquiry plays in their instruction and is included in the model under "Beliefs and values about inquiry-based instruction."

Observations and field notes. Researchers use observation to increase understanding of particular cases in qualitative research (Stake, 1995). I used insights from my interviews to further inform and refine my inquiry and observations. I conducted naturalistic, semi-structured observations of teacher instruction in the BSAA classroom basing my observations in part on the answers participants provided during their interviews. For example, if a teacher related to me in their interview that they loved learning via hands-on methods and disliked having to memorize facts, then I allowed that knowledge to guide my observations. Emergent data continually shaped my focus as well, which guided further investigation.

Researcher's record. To aid in reflection and reflect on subjectivity, I kept an audio record to reflect on salient experiences. This was accomplished by recording audio notes in my car as I traveled from research sites.

Data Analysis

Analysis of the collected data was used to identify patterns, significance, and trends and themes. As trends and themes were identified they informed questions for subsequent interviews (Saunders, Lewis, & Thornhill, 1997). I used the constant comparative method (Glaser & Strauss, 1999) as an analytic approach.

Transcription

Following Mergenthaler and Stinson's (1992) protocol for transcribing qualitative data, I sought to preserve the morphological naturalness (keeping word forms and punctuation as close as possible to as it was spoken), preserve the naturalness of the structure of the transcript, and create a script of the recordings.

Coding

I modeled my coding after *Saldana's codes theory model for qualitative inquiry* (Saldana, 2009).

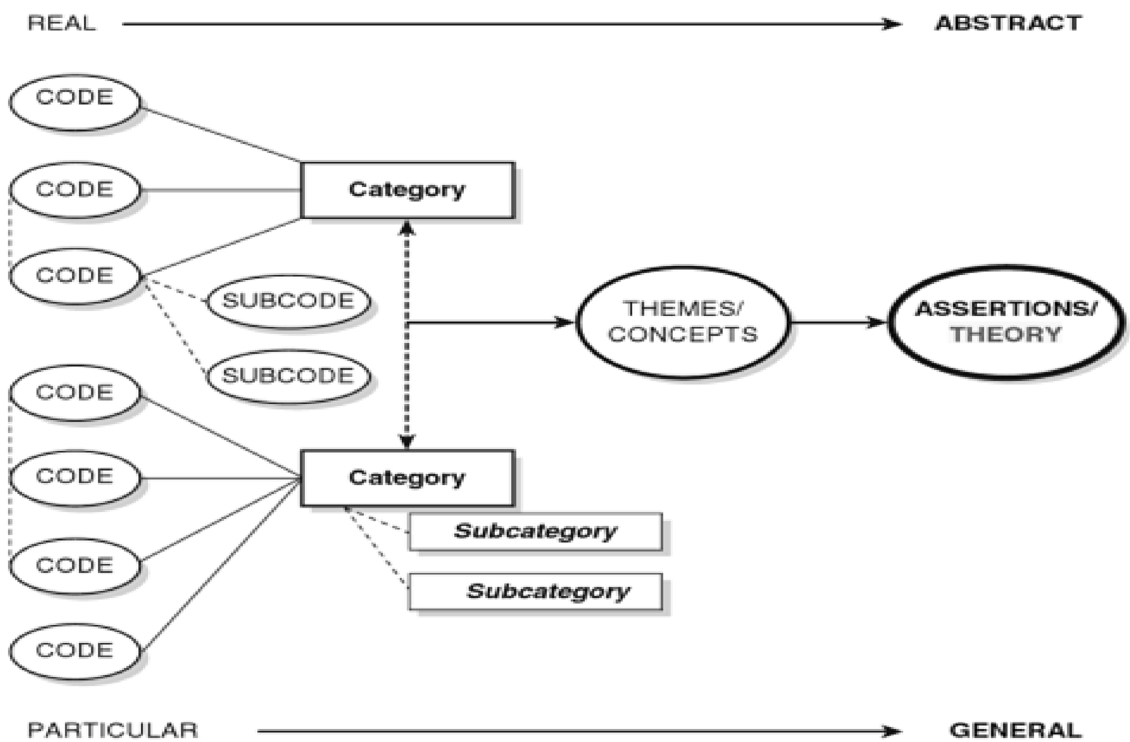

Figure 1. Flow chart showing process by which coded data becomes theory. From "The coding manual for qualitative researchers," by J. Saldana, 2009, Sage Publications.

In this model, when I read a word, phrase, or passage in a transcript that was salient or essence-capturing (Saldana, 2009), I assigned a code to it. As I accumulated a number of codes, I inductively created sub-categories. Tentative categories were created as the process continued. From these categories that shared similar characteristics emerged themes (or concepts), which eventually formed the structure on which I built my assertions (Saldana, 2009).

My coding of interview transcripts, observation transcripts, and observation notes, was informed by the sociocultural model of embedded belief systems. For example, after conducting a general/open code of the data to get an idea of what I had, I coded my interview data using components of the sociocultural belief systems model (e.g., beliefs and values about inquiry-based instruction, course goals, science, and agriculture) as tentative categories. I examined the observational data in a like manner. I later brought the two sets of data (interviews and observations) together and looked for alignment and schisms between the two.

I shared my results with peers and my advisor for additional feedback. The process of coding interviews and observations proceeded iteratively, meaning that the body of codes (lexicon) generated grew both with the addition of new codes and as code definitions were refined.

Trustworthiness and Validity

I have attempted to ensure the trustworthiness of this study and to maintain credibility and dependability. To this end I used triangulation on my interviews, field notes, researcher's record, and observations (Krathwohl, 2009, p.285). Peer debriefing of my transcripts and observation notes was used with my colleagues and advisor, which also helped me to realize insights and organize and interpret my data. I also used member checking by clarifying with participants' salient comments they made to confirm their meaning. To promote dependability, I utilized multiple data collection methods (observations, interviews, artifact collection, and researcher record). I recorded and transcribed each interview and observation and shared the transcriptions with my advisor.

Limitations of the study

One limitation is the forgoing of a large sample for my study. I rationalized that the tradeoff of accepting a lack of breadth in order to obtain the richness and depth I desired was of value. Gender representation may be another limitation in my study, as I selected three men and one woman. However, this representation may be acceptable since as of 2010 14% of the state's secondary agriculture teachers were women. My visits to this quartet of interesting and dynamic teachers were not a chore and were actually very enjoyable, but the reality of needing to press onward with my studies gently reminded me that I could always conduct follow-up or longitudinal studies.

CHAPTER FOUR: FINDINGS

Inquiry

During my interviews of four teachers, a common thread was inquiry. Each told me he/she uses inquiry in their instruction. With my interview data as a guide, I looked for examples of inquiry as I observed their instruction. The teachers seemed to demonstrate inquiry in their instruction in two general ways: in-class activities and discourse with students and their use of projects and activities outside of class hours.

As discussed in the literature review, inquiry can manifest in various ways. The first section of this chapter will provide examples of the indicators of inquiry in the classroom. This list of indices is derived from Doolittle and Camp (2003) and Roth (1996): (a) teacher use of discourse that is conducive to inquiry; (b) instruction based on students' needs, goals, and past experiences; (c) use of small-group and whole-class inquiry; (d) use of authentic and real-world problems. The second section will demonstrate ways in which inquiry is manifest outside of instructional time, including long-term projects and supervised agriculture experiences (SAE).

Teachers – The Cases

Mr. Black.

Teacher use of discourse that is conducive to inquiry.

Episode I. Mr. Black is leading his students in an exploration of photosynthesis. He has had them working in groups to describe the light-dependent and light-independent reactions of photosynthesis and reporting their two lists of findings on the blackboard. During the summary, the class is reviewing the lists when a student asks a question:

S: Do we need to write all this down?

Mr. Black: I would have it down, yeah. If you don't understand the light dependent and the light independent reaction, I would uh... definitely jot it down.

Mr. Black: And so the CO_2 from the carbon fixation, the hydrogen that's given up from the NADPH are then combined to produce glucose and fructose, and that's the end result.

S: Oh! That's it? That's all we have to write? Wow, I had a lot more... I wrote the 'Calvin-Benson Cycle'.

Mr. Black: Well, OK, let's talk about the Calvin-Benson Cycle.

S: Whoa, no! [The other students] don't have to talk about it...

Mr. Black: Yeah! What do you have?

S: It's pretty long...

Mr. Black: Well, break it down for us. Summarize it.

S: All right, well... I wrote it takes place in the schhhh..... stroma, in the chloroplast.

Mr. Black: OK.

S: Begins the five-carbon phosphate and combines with CO_2, which is carbon dioxide, and a six-carbon phosphate is formed. And then that splits into two, three-carbon phosphates, and then those form simple sugars like fructose and glucose. Is that right?

Mr. Black: Yeah!

S: Do I have to write that or not...

<Other students are shaking heads ‘no’>

Mr. Black: That's essentially this <pointing to board>.

S: <Simultaneously with Mr. Black> That's basically what that is, right? That's the same as this <pointing at board>.

S: So why do we call it...

Mr. Black: <Simultaneously with student> You're just giving a title to that. <pointing to the board>

S: Ooohhhhh... <student realizes the connection>

The point Mr. Black was making is that the Calvin-Benson Cycle is the 2nd step in the dark reaction, not a separate process, a misunderstanding the student held. In instances such as this, a teacher could have easily clarified the point they were making and moved on with instruction, conserving instructional time. Instead, once Mr. Black recognized the misunderstanding he demonstrated his commitment to student learning by walking the student through the logic and helping him realize his misunderstanding on his own. This process of “walking the student” through the logic of the problem seems to be similar to the process of “effective tutoring.” In tutoring, the teacher uses questions to coach a student through a solution path (McArthur, Stasz, & Zmuidzinas, 1990). Questions are also used to assess student knowledge and understanding or to focus the student’s attention on specific aspects of a problem. With these questions, the teacher can “scaffold the student’s efforts in selecting and taking certain paths leading them to the solution” (Roth, 1996, p.193). Mr. Black said in his interview that he looks forward to these instances of student misunderstandings when “things do not turn out right, [I like] helping kids think through why and what possibly could have gone wrong. I love that, it's a great teaching tool, a great learning experience.”

Episode II. In this second episode about grain and fungi, Mr. Black is facilitating a discussion his class is having about the nature of small red spots that appeared with some wheat seeds. Students noticed the spots the previous day in class, which led to a discussion about the origin of the spots. The conversation continued to the next day:

Mr. Black: What were our best guesses yesterday, as to how is the mold getting nourishment?

S1: It's taking the seed's nutrients.

Mr. Black: It's taking the seeds nutrients.

S3: Or breaking down the paper towel.

Mr. Black: Breaking down the paper towel.

S4: Or both.

Mr. Black: Or a combination thereof.

Mr. Black: Now here's my question: this one about the seed is interesting... that it was using the nutrients from the seed. But the question is; why wasn't the mold growing on the seed? Instead it was growing a little ways from the seed on the paper towel? I mean, that's where it was, right? It wasn't right on the seed.

S: Yeah.

S1: Maybe the seeds got moved around when we opened up our container.

S: Yeah, we didn't open up ours slowly, we just opened it up.

S2: Or the chemicals that they give off... <garbled>

S1: Maybe they leak around and then changed to mold...

Mr. Black: What do you mean, leak around? What leaks around?

S: Like if it was in soil, it wouldn’t like, be directly on the seed, it would have leaked into the soil, whatever it is... then mold would start growing somewhere else.

<After 40 minutes of discussion, Mr. Black brings the discussion full circle and initiates a summary>

Mr. Black: What did we say mold needs?

S: Mold eats sugar.

Mr. Black: And?

S2: Food.

Mr. Black: Food! Sugars! Hmmmmm.

Mr. Black: <In a very soft voice> Mold eats sugars... the sugars are in the seed, once the starch is broken down, is it possible that the sugars actually leaked out of the wheat seed? Is it possible that the sugars leaked out of the micropile?

S: Yeah!

<Multiple students comment excitedly>

S: Yeah, because sugars are flowable.

Mr. Black: Because they're flowable. They're soluble.

S: That's really cool.

S2: So *that's* the answer to the question!

Mr. Black: Does it make sense?

S1: That took a *while*.

Mr. Black: Does it seem reasonable?

S: Yeah.

Mr. Black: That *was* a lot of work for a short answer.

<Class getting loud, students packing up>

S: Yeah!

Mr. Black: Well guys, remember; I told you in science sometimes we come up with answers, sometimes we come up with more questions, and if we quit coming up with questions…

<Student interjects> We lose our jobs!

Mr. Black: ...we lose our jobs.

This second episode could be taken as an example of Mr. Black's use of discourse that is conducive to inquiry. When the student suggests that the "chemicals leak around," Mr. Black asks him to clarify his meaning. After the student provided an answer Mr. Black did not tell him out of hand if he was right or wrong, but instead challenged the student to help him to learn and to confirm his understanding. The eventual point made in class, that sugars are flowable and soluble, took the class two and a half class periods to realize. However, it is likely the students will well remember, and have a deeper understanding, of this content. "Deep understanding comes from being immersed in a subject for a long period of time. Superficial coverage does not help students develop competencies because there is not enough time to learn anything in depth" (Friesen et al., 2013, p.12). Mr. Black told me he does not worry about the amount of time he spends on individual topics or managing to teach everything he plans to teach. "I don't get too involved with that, it does not bother me. I am more concerned with what we do cover, are they actually getting, rather than looking, at some scope… I have identified what I think is most important, and move from there. If we get to all of it, fine. If we don't... fine."

Based on students' needs, goals, and past experiences.

Episode III. The next episode is also part of the wheat seed discussion. Mr. Black is discussing starches with his students:

Mr. Black: Although they're stored in protein, in the seed itself the embryo can't use that starch in its current form. Something has to happen to it. How many of you have done a lab in biology where you have looked at a starch being broken down?

S: Pretty sure we did.

<Multiple other students answer>

Mr. Black: Pretty sure you did?

S: Yeah.

Mr. Black: Can you describe what you remember of it?

S: Well, give us a little example of how you we might have…<garbled>

Mr. Black: Well, if I do that, I'll give you the answer… <interrupted>

<Class laughs, everyone talks. A different student asks for the question again>

Mr. Black: OK, have you ever done an experiment where you looked at a starch to see if it broke down into smaller compounds?

S: Yeah!

S2: We diffused it into something...

Mr. Black: You diffused it! Oh, you probably did, did you ever use the little dialysis bag?

S: Yeah! Yeah...

Mr. Black: Dialysis bag, you put some fluid in it, put some other stuff in it, tie it off... put it in a beaker of water...

<Many affirmatives from students>

Mr. Black: What was that all about?

S: It was how, like, how water moves across a barrier...

Mr. Black: How water moves across a barrier. All right.

<More students comment, about ‘adding dye to a bag’>

Mr. Black: And you added some color to it?

S: Yeah, it was blue.

Mr. Black: What was blue?

S: The inside, the liquid on the inside was blue.

<Many student comments, about ‘it changed’, ‘put it in like water’, ‘changed color’>

S: We put it in the blue water, and the water in the bag was clear, and took it out and the water in our bag was blue.

S2: It, like, changed colors, yeah.

Mr. Black: OoooOOHHHHHhh, so, OK.

Mr. Black: When starch is broken down, what is it broken down into?

S: We learned this last year. Is this a biology question?

Mr. Black: Yes, it *is* a biology question. What are starches broken into?

S: Monosaccharides.

Mr. Black: Monosaccharides. That's a fancy name for saying what?

<garbled student response>

Mr. Black: Well, those are different. Monosaccharides, disaccharides, polysaccharides. What are they?

S: They're sugars!

Mr. Black: They're *sugars*, right?

I interpret this episode as Mr. Black demonstrating how he bases instruction on his perception of students’ needs, goals, and past experiences. As the conversation about starch proceeds Mr. Black calls upon his students’ previous experiences to provide reference to what they are learning now. His comments, “Did you ever use the little dialysis bag?” and, “Yes, this is a biology question,” appear to demonstrate Mr. Black is intentional in his use of scaffolding.

“I tell students coming in, completion of the biology class here is one of the prerequisites.” Mr. Black says it is important that his students have all been successful in biology because he needs to know they have a specific background in biology on which he can draw. This may be an example of how a teacher conveys relevance to content by helping their students to draw connections (Newcomb, McCracken, & Warmbrod, 1993). “My goal [for] the class is that they are thinking and engaged cognitively and not simply memorizing facts and figures. Hopefully it will give what they memorized in biology some relevance to what they learned in BSAA.” “The other thing I would say is, I don't have to know everything as a teacher, and I have never pretended that I know everything. The inquiry model allows us to learn together and I'm a huge proponent of that. From day one, the problem solving approach allows us that opportunity to learn together with the students.”

Use of small-group and whole-class inquiry, Authentic and real-world problems.

Episode IV. Consider these next two excerpts. In the first, Mr. Black is attempting to ascertain if his students can apply their knowledge of photosynthesis to real-world problems.

> Mr. Black: “It’s great that you can define photosynthesis, name the chemical in it, etcetera, but this class is biological science *applications* in *agriculture*. How do we *apply* this knowledge?”
>
> < Mr. Black provides the students with a scenario> A grain farmer, a produce farmer… are concerned with what? What is their ultimate goal?
>
> S: High yields.
>
> Mr. Black: Yes. High yields. And so, does photosynthesis effect yields?
>
> <Students nodding>
>
> S: Yes.

Mr. Black: You would say so, yes. How many of you would agree that photosynthesis probably affects yields? <students raise hands> Now, what does *yields* mean? For anybody that may not know this...

S: It means, ah, bushels per acre.

Mr. Black: Yes, how much they produce. How many of you would agree that photosynthesis probably affects how much a plant produces?

<Counting hands>

Mr. Black: <To a student without hand up> Do you disagree Kelsey?

Kelsey: <mumbles> No.

Mr. Black: No? You don't disagree, so you do agree? OK. Good!

Mr. Black: Let me ask this question. Let's take a corn plant, for example. In small groups here, I want you to consider this. How would you change a corn plant, from a photosynthesis point of view, to make it photosynthesize more efficiently? I want you to dream a little bit here.

The class splits into four groups of four, and discusses the problem in their small groups for ten minutes.

Mr. Black: All right, let's share your ideas. I want you to be thinking about, when a group says something, offers an idea, before they explain 'why', I want you to think about how you think that idea would impact photosynthesis. And then we'll let them explain. And then we'll ask questions, “Would this improve photosynthesis, cause other problems, etcetera, etcetera?”

S: Our idea was make the corn plant not dependent on light, so that it could work in nighttime too.

S1: <Interrupting S> I thought we were supposed to be making it...

Mr. Black: <Interrupting S:1> Whoa whoa whoa. Hold on.

S: <continuing> It could work both night and day, so it would not just have to work half the time.

Mr. Black: So what I think I hear you saying is, the plant could photosynthesize in complete darkness?

S: Yes.

Mr. Black: Or, it could carry out the photosynthetic process in light, or it could carry it out as it currently does in a combination of light and dark.

S: It would get more yield because we could potentially grow the crop in half the time and then grow a second crop.

<Students start to chime in, discuss>

Mr. Black: That's an interesting concept I hadn't considered.

S1: I thought the whole point of this was to make the product more acceptable to light?

Mr. Black: They're just looking at it from a different perspective. I just said, 'How could you change it to improve...'

S: I thought it was to make it more receptiful [sic].

Mr. Black: What you're saying is not wrong. But, my question to them was this... well, let me pose it to the class. Do you have any questions about how they could possibly... what considerations would they have to make to allow a plant to photosynthesize in the dark?

S2: Proximity to other plants?

Mr. Black: <curiously> How is that going to... how does proximity to other plants relate to the idea of allowing to photosynthesize at night, in the dark?

S2: Because it's in the dark there is only so much light to take in.

Mr. Black: They're saying pure dark, no light.

S2: Oh... <to himself> it has to have light for photosynthesis.

Mr. Black: But the question was, how can we improve the corn plant, and they're saying, ‘Let's let it photosynthesize without light. Let's figure out some way to do it.’

<Class is stumped>

Mr. Black: Go back to the light dependent actions. What would be missing if there was no light?

S3: Trap light energy?

Mr. Black: OK, so they're not going to need to trap light energy. Why is the light energy so important?

S: Because it is essential to the processes.

Mr. Black: And specifically what does it do?

S: Electron release?

Mr. Black: Electron release, and what is that used for?

S: Water splitting?

Mr. Black: To split the... how... remember, the split of the water molecule is where we get the hydrogen to mix with the carbon dioxide to make the sugar. So, if there's no light to split the water molecule where's the hydrogen going to come from to make the sugar?

S: Can't the plant just split it on its own?

S4: That's kind of like saying, that, they did the same thing, just without light, as they're doing right now.

Mr. Black: Right, that's the question. How would the plant have to acquire hydrogen, what would be possibilities to acquire hydrogen that is in elemental form so that it could be used, or is there something else that could possibly happen that could release hydrogen.

S2: They could make the plant so it uses other types of radiation instead of the visible light spectrum, in the dark?

Mr. Black: <surprised> Oh! So, are you suggesting that even at night there is some radiation?

S2: Uh huh.

Mr. Black: OK. True. So maybe the plants use other parts of the electromagnetic spectrum rather than the visible light and the portion just beyond that. Yes?

S6: Could we modify the way in which corn takes in nitrogen? Like, from the air? Like some plants take in hydrogen from the air.

Mr. Black: Yeah, the legumes do but corn doesn't.

S6: But, maybe alter that corn so that maybe it could suck in nitrogen?

Mr. Black: Ah! So what he's saying here is what if the corn plant could fix the hydrogen from the air and use that for photosynthesis, and not have to rely on light energy to split the water molecules? Yes?

S: Or change it, hydrogen, to a solid or a liquid, and like spray it on the corn plant or like get like a powder and drop it on them?

Mr. Black: OK, figure out something that we could apply to the crop to supply the hydrogen. Another interesting idea. OK. Good. Let's go to your group...

<Other groups suggest ideas such as broaden the leaves, increase the number of roots, darker leaves, longer and taller plants>

I perceive Episode IV as demonstrating Mr. Black's use of small-group and whole-class inquiry. The activity he chooses has students considering how they would modify corn to make it photosynthesize more efficiently. Without overtly telling them, Mr. Black is having his students draw from course content they have learned, to evaluate and create a novel solution to the problem presented. Assumedly corn is relatable to their lives and past experiences, which would reduce contextual barriers to participation. If this is the case, then the topic of corn is a good vehicle to stimulate thought. I think the use of small-group, problem-based learning is appropriate in this instance because it replicates the systemic approach to resolving problems or challenges encountered in life (Wood, 2003).

Mr. Black concludes by tying the discussion into the real world: "Scientists are asking these very questions right now, somewhere. These questions you posed are legitimate and authentic and are actually being pursued by real crop scientists." I interpret this as a demonstration of using authentic and real-world problems in instruction.

Episode V. In this fifth episode, during class one day a student spontaneously approaches the class for help with her long-term project:

Mr. Black: OK, McKenzie, state your question again. We're going to try and troubleshoot this, try and figure it out.

McKenzie: Why does [sic] our seeds germinate better here than they do at home? Like, why would it take longer for seeds to germinate at home than it does here?

<The class appears unsure. Mr. Black opens the floor to questions from the class>

S: We have the light thing out by the fish tank. That's pretty powerful and gives off a lot of heat. Are you using anything like [that supplemental lighting], or are you using this kind of lighting <pointing to ambient light in room> at home?

McKenzie: It sits in the kitchen. <Class chuckles> <McKenzie looks embarrassed>

Mr. Black: It sits in the kitchen. OK, that's fine. So, are you suggesting that it's light or heat?

S: Cause that gives off heat, and light, over there, and that's where we use it with the plants. It's warmer compared to like room temperature.

McKenzie: It's like, by a window…

Mr. Black: It's by the window.

McKenzie: … hmmm, maybe it gets cold by the window?

Mr. Black: So possibly it's not as warm? And when we studied germination…

S: Seeds need warmer temperatures to germinate.

Mr. Black: So you think it *possibly* could be temperature?

McKenzie: Yeah.

Mr. Black: OK. What else?

S1: Like, there's a lot more control here, than there would be at your house… I think.

S2: Perhaps.

Mr. Black: Perhaps.

S1: Cause, you don't have, I don't know your yard or anything, but if you have like, tree limbs that blocks the sun, it's not going to get as much light. Here there's nothing blocking the greenhouse, so you're getting light.

Mr. Black: But her's are growing right out here…

S2: Yeah, I'm talking about under that light…

Mr. Black: …in the shop.

S2: …there's a wall there. The only thing that was [providing light] was that light.

S1: <To Mr. Black> Didn't you say that light was better than sunlight?

Mr. Black: Oh. Is it better than sunlight?

Mr. Black: I wouldn't say better than sunlight, but it's very close to the spectrum of...

S3: So you probably wouldn't want to stare at that thing for very long...

Mr. Black: It is designed for plant growth. And no, you probably shouldn't stare at it.

Mr. Black: Any other possibilities of what might be going different at home rather than here at school?

S5: Is it a constant environment? Door goes open, door goes closed, it gets cold,

S3: It's close enough.

Mr. Black: I understand what you're saying. Do you think there would be more variation at her house than in our shop?

S4: Yeah, that's what I'm saying. Perhaps, is there an extra door in the kitchen?

Mr. Black: Why?

S5: I don't know if this has anything to do with it, but you said that it's always on, like eight to ten hours, which is pretty consistent. Do the kitchen lights at home, stay on longer some nights than they do other nights?

McKenzie: It's not directly under the kitchen light, it's like, by the window, so like the only light it would get during the day would be daylight.

S6: Maybe the consistency of the water?

Mr. Black: Consistency of watering?

McKenzie: I don't water them. <The room is silent for two seconds, then erupts in good-humored laughter, including teacher and observer>

S4: All right! <slapping hands together> Well, *that* solved it. Figured it out!

McKenzie: Oh! No, I know, because it's in a paper towel, so I don't add anything.

Mr. Black: Oh, oh, oh. OK, I got what you're saying.

S2: Do the towels dry out quickly?

McKenzie: No, they haven't.

Mr. Black: So it's not that there isn't enough water. You don't think that's it. You guys keep bringing up light. Do seeds typically need light to germinate?

<Multiple "No's", shaking of heads>

Mr. Black: There are a few, but typically they only need what, to germinate?

S3: Water. Temperature.

Mr. Black: And oxygen, right?

McKenzie: Maybe I should move them, away from the window?

S5: Move them over a heat vent. It will speed it up.

S2: You're in a cold window versus a warm temperature.

McKenzie: Ohhhh.

Mr. Black: What do you think?

S4: But don't completely cover it up, set it on, like, a grate.

McKenzie: I could get, like, a space heater, put it by it.

S3: You don't want to melt them.

S4: You could put it on one of those locker trays they got. Or a milk crate.

Mr. Black: Does that make sense to you?

McKenzie: What?

Mr. Black: They're saying they think it's probably temperature.

McKenzie: OK, so maybe I should move it? Away from the window.

Mr. Black: To get a more constant warm temperature.

S5: Move it towards the center of the house, near a heat vent.

S2: Far away from a window. Where it's cold.

S4: Where there's no drafts. Do you have a radiator?

McKenzie: Yeah, in the living room.

S4: Put it by that.

S2: Not on it, but near it.

S5: I put mine by one of them propane heaters, the ones that are on the wall? I put it below it, on a red wagon.

McKenzie: OK, I'll try it.

Mr. Black: Report back on Monday.

McKenzie: I'll see if that did it.

This passage appears to demonstrate effective use of inquiry-based instruction. Student-centered activities where students pursue projects in small or large groups "are occasions for children to complement their peers, ask questions, or provide suggestions for improvement of their peers' structures" (Roth, 1996). The discussion was based on student need, prompted by a student's request for help with a real-world problem with which she was struggling. The entire class pitched in to solve the problem, which appears to be an example of whole-class inquiry. Students were able to draw upon their knowledge of agriculture and science while attempting to solve this real-world problem by asking questions and weighing responses. Finally, Mr. Black allowed the discussion to flow, moderating without dominating the conversation.

Mr. Black summary. Mr. Black's problem-based learning approach to instruction potentially means that his students are often exposed to inquiry. Due to the nature of instruction, his students should enjoy a great deal of freedom in class as they engage in small group collaboration. It would appear that this learning environment promotes student engagement, as evidenced in the transcripts. During my observations, Mr. Black depended almost solely upon the problem solving approach.

Mr. Green. Carlsen (1988) and Roth (1996) write that various non-student-centered instructional practices can be discouraging to student engagement. Teachers that dominate the speaking floor, make frequent requests for low-level factual information, and "disregard student bids to change the current topic" may realize reduced student participation (Carlsen, 1988; Roth, 1996).

Teacher use of discourse that is conducive to inquiry, Instruction based on students' needs, goals, and past experiences.

Episode VI. In this episode Mr. Green's class is studying genetically modified organisms (GMOs):

> Mr. Green: A growth chamber in this case includes a greenhouse, as well. What is a growth chamber?
>
> <No response>
>
> Mr. Green: It is an enclosed environment and it is designed to control all the different influences on the plant by the researcher. I can control the temp, I can control light, I

control humidity, I control water, I control insects, and I control the soil. I control everything. Going back to the research, why do I want to control everything?

<No response>

Mr. Green: Why do we control research?

S: Ummm... why else...

Mr. Green: Huh?

S: How do things mess up results?

<No other responses>

Mr. Green: OK everybody, stop what you're doing. Look up. I see all you guys are paying attention to other things. How and why do we control research?

S: Because everything that has to do with it is a variable.

Mr. Green: Variables! Absolutely. If I'm growing this lettuce plant and I'm comparing it to a plant that is non-transgenic, and I want to see how it grows or is it safe, I need to compare them side by side, and I need to have the same conditions for both of them, except one is transgenic. Temperature needs to be controlled, humidity, insects, so that the research is valid. Variables are present. The growth chamber is the first stage. Growth chambers can range from small boxes on a table that have really dynamic controls on it all the way to essentially a greenhouse. At research facilities they have growth chambers and greenhouses. This year when we go to explore ACES at UIUC, you guys go in the greenhouse tour at the university and in the basement of the greenhouse there's these growth chambers in the basement, and you see they are small growth chambers, to the greenhouse itself is a growth chamber. They want to control all of these strange variables, but the only thing they are comparing is the independent dependent variables.

Mr. Green: Once we know the plant will do what we want it to do, we can go into field trials. What are field trials?

S: Testing it in an environment?

Mr. Green: For what reasons?

S: To know the outcome for the farmers?

Mr. Green: True! What else? What's the difference between a growth chamber and a field trial?

S: It's not controlled.

Mr. Green: It's not controlled, and it's going to tell us how tough a plant is. All I can think of is whether the plant is tough or not. Can it survive the variables that come it, can it survive an insect, can it thrive? What does it do in a natural environment? That is the question. I can grow a lot of plants in that greenhouse out there, but take them outside and they die. Pineapples, plant them in the greenhouse, OK. Plant them outside, they are not going to survive. In a growth chamber I can grow them, because I have control over all those variables and things like that. So, does it work in the environment? Does it work in the environments we are going to use it in?

Mr. Green: But that's not it, let's go down through to the bottom, down to ‘C’ there; field trials. There's several different types, the first is called a varietal trial. What do you think a varietal trial is?

<No response>

Mr. Green: What is a variety?

<No response>

Mr. Green: What am I testing in a variety trial?

S: Characteristics?

Mr. Green: Of what?

<Shoulder shrug from student>

Mr. Green: *Read* it! It's written word for word in your [guided] notes.

S: Their… how they act compared to the original.

Mr. Green: All right. I've got the papayas, for example. I've got rainbow and I've got the traditional non-GMO papayas. I'm going to plant them in the same field, because they are going to get the same environment, the same bugs, the same all the same conditions, all the same variables, but I want to compare them side by side. How do they compare to their counterpart? Which variety is the best? Which variety is not? We this year, our FFA chapter, did a variety trial for Pioneer Seed Company, and in our field we planted 12 rows of six different varieties across out field. And then we came to harvest, we harvested them one row and a time, collected them, figured out much grain was being produced, and we took information from those varieties so that Pioneer Seed Company could compare those varieties in all the types of fields all over the country before they started selling. So we had six varieties of seed that nobody could buy. Comparing these seeds against varieties side by side by side by side against all those seeds around, and so that's a varietal trial.

Episode VI appears to present differences in practice between Mr. Black and Mr. Green. During my observations, Mr. Green used a great deal more lecture than did Mr. Black and Mr. Green's students appeared to be less engaged than did Mr. Black's. According to Zachry (1985), a lack of student engagement resulting from lecture-based instruction is predictable. Inquiry-based instruction differs significantly from traditional lecture, as inquiry requires student involvement and active participation (Zachry, 1985). On one instance, after Mr. Green asks his class to define “growth chamber,” I observed them sitting silently, non-responsive. Instead of clarifying or rephrasing the question Mr. Green provided them the answer and moved on. Zachary (1985) might say that this form of discourse, in which the teacher just tells the students the answer he or she is seeking, is not conducive to inquiry. From the lack of student response it appears that his class may not be interested and/or may not have the foundational knowledge to respond.

Mr. Green’s questioning asks for responses of explicit, factual information. “What is a growth chamber,” “What are field trials,” and “What is a variety?” While facts are important to know, this form of questioning may not be conducive to inquiry. As Roth (1996, p.2) writes: “To bring about conceptual change in science, good teachers use questions to elicit student explanations, elaborations of previous answers and ideas, and predictions that contradict students’ intuitive ideas about natural phenomena.” “Good questions provoke thought, are based in students’ experiences, and call for creative thinking” (King, 1994). Questioning for canonical knowledge does not require creative thinking nor provokes conceptual change in students (Grasser & Person, 1994).

Use of small-group and whole-class inquiry, Use of authentic and real-world problems.

Episode VII. Later in the same class, Mr. Green talks to the class about varietal testing.

Mr. Green: What's the first things we should test?

S: Safety.

Mr. Green: Safety! Safety trials are done exclusively before we get into any variety trials. Is this plant going to have a negative effect on the environment? For example, I wanted to create a Roundup resistant plant, and so I got all these Roundup resistant plants. I spray

Roundup on it and they don't die. What is a plant that you would not want to be Roundup resistant?

S: A weed?

Mr. Green: Well, remember, all plants are weeds in some cases. What are some plants that we specifically, would not want Roundup resistant?

<No response>

Mr. Green: Would we want all of our turf grass to be Roundup ready?

<No response>

Mr. Green: What if that turf grass keeps on spreading and spreading and spreading and spreading, how do we kill it if it starts to spread?

S: With Roundup?

Mr. Green: With Roundup. So I would not want to... the only thing I could do to get rid of that turf grass is to pull it up, dig it up. That's tough sometimes. Some of our turf grasses would be OK, they don't spread like other turf grasses. Some of them spread and crawl around, and I would not want to put in them Roundup resistant, because that grass, once it gets in that environment, there's nothing to stop it. There's no native plants that are going to outcompete it, it will choke out the other plants. So I would not want to create a Roundup specific type of turf grass, like blue grass, or Bermuda grass. That would be dangerous in an environment. Plants we grow as crops are like first cousins to weeds we have that are really dangerous around here, and the last thing we want to do is have a cousin of one that is out there that is resistant to Roundup and it's cousin the weed is next to it, they can cross pollinate, and they can breed. We can test to see if they *do* cross-pollinate, does that weed now become resistant to Roundup? It's tough. These are the kinds of safety trials that have to happen before we get to the production of a product. If it's a food product, we have to see if it is safe for us to eat. Transgenic papaya, we don't start feeding it to people, see if somebody gets sick, take it off the shelf. You have to test that kinda' stuff. How do we test those kind of things?

S: Give them to pigs?

Mr. Green: Animals. We feed them to animals, generally there's animal testing. Man, that's pretty messed up. OK... I see it, if it were my dog, I wouldn't volunteer my dog, to do the test, but at the same time, what's the alternative?

In this episode, there would appear to be multiple instances for Mr. Green to engage his students in inquiry, but when students provided answers there seemed to be little follow-up or probing to confirm the student's understanding. The reason this choice was made in this instance in unclear. In episodes VI and VII, while Mr. Green uses real-world examples to engage his students, they seem to be only illustrations, not distinct activities for the students to explore. This seems contrary to indicators of use of authentic and real-world problems.

Episode VIII. On another day, Mr. Green is leading a discussion about the food science topic of making ice cream.

Mr. Green: How many of you have studied the effect of salts and sugars on freezing objects?

S6: Oh! When you put salt on your napkin, it makes it not leave a ring around your napkin.

S5: Or, when you put salt on an ice cube, and a piece of string, it…. I don't know, um…

Mr. Green: *OK* then! Moving on. OK, it's January, and you walk out your front door, and you…

S6: You slip on ice!

S: Melt it!

Mr. Green: What do you do?

S6: You fall down!

Mr. Green: You go get salt, put salt down.

SX: <Much shouting of answers, replies>

Mr. Green: What does the salt do?

S7: Chemical reaction!

S5: Friction, walking on it!

S4: It eats the ice, it eats the ice!

Mr. Green: <To student 4> So, how many salt molecules do you know that have mouthparts?

<Laughter, boos>

Mr. Green: OK, salt lowers the freezing temperature.

S7: One time my brother put salt down and got in trouble, because it was too cold. Dad got mad because he wasted salt because it does not work.

Mr. Green: So, why does it have no effect?

S1: Sublimation!

Mr. Green: No, not sublimation.

<Other comments and guesses from students>

Mr. Green: OK, so here it is. Salt lowers the freezing point of water.

Mr. Green: OK, these crystallized solids take the freezing point and lowers it.

S8: Can you take milk and everything, add salt and syrup and make ice cream?

Mr. Green: No, but good question. *So*, what crystal do we add to the milk?

SX: Sugar!

Mr. Green: So, the sugar lowers the freezing point. So, if I add too much sugar to the ice cream, will it freeze?

S1: No!

Mr. Green: No, not really, unless I have a really, really cold freezer. We want to add sugar to make ice cream sweet, but we don't add too much sugar to keep it at a manageable freezing temperature.

S7: What about Splenda?

Mr. Green: The same, it is a crystal.

S7: Because, I thought [it might be different because] Splenda is a sweetener, but it's not sugar.

Mr. Green: Yeah, but it's still a crystal.

This interaction presented Mr. Green opportunities to lead his students in discussions about authentic and real world problems. Mr. Green asked about walking out one's door in January, and I perceived his students were not providing him with the answer he sought. Instead of rephrasing the question he chose to give them the answer he wanted and continued onward. When Mr. Green asked, "What does the salt do?" he received a number of conjectures from his class; "chemical reaction," "friction, walking on it," and "it eats the ice." Any of these three responses could have been explored and expanded, as they all were possibly valid as far as the students were concerned. After making a joke about salt having mouthparts he responds by providing the students with the answer he wanted, "Salt lowers the freezing temperature [of water]." This may have been an excellent opportunity for Mr. Green to engage his students by elaborating on their responses to overcome their misconceptions (Arons, 1990). By making predictions, elaborating, and explaining, students develop competency and deeper understanding of curriculum (Smith et al., 2000).

Later, Mr. Green asked why the salt has no effect. A student replies, “Sublimation!” This could have been an excellent opportunity for Mr. Green to ask the class for a definition of sublimation, or ask the student to explain her rationale, instead of seeming to dismiss the response out of hand. A student inquired, “Can you take milk and everything, add salt and syrup and make ice cream?” Mr. Green’s answer was a quick, “*no*, but good question.” He very quickly moved on with no follow-up. This method of instruction may lead to disinterested students, as Carlsen (1988) writes that teacher questioning that seeks “terse and factual responses” discourages student participation (Roth, 1996).

Mr. Green summary. From what I observed, Mr. Green’s instruction relies mostly on lecture and asking simple and factual questions of his students. Roth (1996) says lecturing is not engaging to the student and is therefore less effective to teaching (and also for effective teaching of inquiry). This may have been demonstrated in Mr. Green’s classroom when his students often appeared to be disengaged and disinterested.

Mr. Green says taking time to introduce students to inquiry can be challenging. “Some teachers really do just cut them loose and let them build their own experiments from very early stages. I'd be interested to see what some of those teachers do and how they do it, and the type of students they have, because I'm not comfortable enough to do that yet. As a teacher, to just cut them loose and figure that out on their own sometimes, even though I probably should... sometimes I probably should.” He says it is difficult for him to get students to “think.” “That's one thing that we have to really struggle with them. In general, getting kids to not want to just regurgitate information. Getting kids that really want to truly find answers to solutions, not just figure out, a lot of these kids are programmed to just regurgitate information."

Mr. Green said that he tries to cover his curriculum but he's always short on time. "It's like, what kind of time do I have, what other lessons can I fit in that timing?" "It is especially difficult because it takes time to use inquiry with your student." "You've got to train them, and that takes time to train them to even think that way. And you've got to help them practice that, and that's challenging." I observed the challenges Mr. Green faced during episode VIII. Although he was having the whole class discuss the topic of ice cream, I observed that students seemed to have no voice in the topic or the direction the discussion was taking. This would seem to be contrary to effective use of group inquiry, as discussed by Doolittle and Camp (2003).

Mrs. Flowers. When I interviewed Mrs. Flowers I asked her if she uses inquiry-based instruction with her students. She replied, "Explain what you mean by that, in terms of BSAA?" After I provided an example she said, "Uh, yeah. The way that the curriculum is designed there are labs out there, but I do try to do that."

Teacher use of discourse that is conducive to inquiry.

Episode IX. In this episode Mrs. Flowers' class is learning about organic soil amendments:

> Mrs. Flowers: What are worm castings? You don't have to answer that question... yet. We are going to get there. Do you need to write anything down right now? Now, I am going to put up a little PowerPoint here, we're just going to have a quick discussion, and like I said, you don't have to write anything down we're just going to talk about this.
>
> Mrs. Flowers: Alright. What are worm casting? They look like this.
>
> <Holds up a container of castings. Multiple "ooh's" from students>

S: Sweet!

Mrs. Flowers: Yeahh!

Mrs. Flowers: You guys are welcome to touch it...

S: OK! I'm holding them!

Mrs. Flowers: OK, so as I am going through this and talking a little bit about what worm castings are, go ahead and pass this around. You can look at it.

S: It looks like dirt!

S2: Scary.

Mrs. Flowers: Please don't spill it! That would be gross, and all over my floor. OK, so... what are they? Somebody raise your hand and tell me what did you research and what did find? Yes, Sadie?

Sadie: <Reading verbatim from her paper> A mass soil mud sand thrown by an earthworm.

Mrs. Flowers: OK... umm, say it one more time.

Sadie: <Slower> A mass of soil, mud, sand... or sand thrown by an earthworm.

Mrs. Flowers: OK, so... a mass, of like, mud and soil and stuff that is thrown by an earthworm?

<Garbled student discussion>

S: I don't know how to explain it...

Mrs. Flowers: No, I got you. That's good, that's a good start. What else did we find?

S: Well, I put, “Thrown up by an earthworm.”

Mrs. Flowers: OK, so she says thrown up by an earthworm. Evan, what do you have?

Evan: The soil that is the product of vermicompost?

Mrs. Flowers: OK, the product, which is vermicompost. That's a good scientific word. Excellent. What else did we find? Anybody else find a more simplified version?

S: Worm poop!

Mrs. Flowers: Worm Poo! Alright! Yeah, you guys are... You're correct.

Mrs. Flowers: Some of the other terms are a little bit nicer, I think, but really what this is like fecal matter from a worm. Great. Now, did anybody research why this could be a beneficial thing, if I maybe am an agricultural producer, or just a home gardener?

<No response>

Why would this be beneficial? Anybody want to raise your hand and tell me that?

<No response>

Mrs. Flowers: Or just do you maybe not know the answer, but you want to make a guess?

<No response>

Mrs. Flowers: <Softly> Any ideas?

Mrs. Flowers: <To a student> You don't have an idea?

S: No idea.

Mrs. Flowers: You have no idea? OK. Well, I'll tell you first what it is, and we'll get to why maybe we'd use it in a moment. It's a complete, organic fertilizer, which is produced naturally by earthworms. So when I use the word "organic," what do you guys think I mean by that?

S: All natural.

Mrs. Flowers: I heard “All natural,” so this is something that is not manmade. OK, when a worm uses the facilities, which is just... the earth. When it goes to the restroom, is that natural?

S: Yeah.

Mrs. Flowers: OK, it's not manmade. So, very good. This is organic, which is the opposite of inorganic. And what would be inorganic?

S: Processed...

Mrs. Flowers: Yeah, maybe manmade processed... very good.

Mrs. Flowers: So, there's my little worm, who poops a lot, constantly, all day long, that is all it dies, it eats and it goes to the bathroom, it eats and it goes to the bathroom, so... and that's what we do maybe, but how do we benefit from this whole process? Well, I found this product. This is from a website that was trying to get me to purchase some earthworm business...

S: <Interjecting> Fecal matter!

Mrs. Flowers: Here's my castings, you guys are passing it around. So, did anybody actually touch it?

S: I did.

Mrs. Flowers: Did you? Cause you just touched *poop*!

<The class is silent>

S: Oooo!

Mrs. Flowers: How you feel about that?

S: I'm alright.

Mrs. Flowers: It's really not gross, is it? It's really not disgusting, it feels like soil, right? So do you believe all this stuff, do you believe all that we read?

S: <sarcastically> Oh, yeah, we do!

Mrs. Flowers: That it's going to be a product that you should use?

S: How do we know we can trust what they say on the website?

Mrs. Flowers: You don't know that you can trust it?

S: Yeah.

Mrs. Flowers: <Smiling> So, that's the best part... that you get to test it and see if it is going to be beneficial.

Mrs. Flowers: So, you guys are gonna be designing an experiment figuring out whether or not worm castings are beneficial, but along with this, I'm gonna let you do some research and also figure out other types of organic fertilizer. Things like compost, cow poop, if you want to use cow poop, you've heard of, like, fish emulsion? They actually sell that at the garden store. They sell something that I was just ordering that's called "Chickity Doo Doo." I'm not kidding, it's in a bag, it's chicken poop, chicken feces. So, all of those, you guys, are organic fertilizers.

In this episode, similar to Mr. Green, I observed that most of Mrs. Flowers' use of questioning only asks for definitions, which is not usually considered to be conducive to inquiry. Dissimilar to Mr. Green, however, is that she garners a good deal of engagement from her students.

Instruction based on students' needs, goals, and past experiences. Mrs. Flowers says she is committed to student autonomy and tries to promote student buy-in. During the first week of class she asks students for their input. "I like to have the students help me decide what they're going to learn. At the beginning of the year [I asked them to] circle all the labs they wanted to do in the syllabus." I think this is evidence that Mrs. Flowers determines their interests at the first of the year and bases her instruction on students' needs, goals, and past experiences.

Episode X. Mrs. Flowers reviews the nitrogen cycle with her students.

Mrs. Flowers: Today we are talking about the nitrogen cycle. It's just like the water cycle, you learned when you were a little kid, back in kindergarten or first grade. It's similar to the fact that water keeps cycling around Earth, and so does nitrogen. The nitrogen cycle is simply the circulation of nitrogen from the atmosphere, we have a lot of nitrogen, like 70% in our atmosphere, and what happens is that atmospheric nitrogen circulates to living things and then back up in the atmosphere again. The cool thing about this class is we get to see hands-on how it really does happen. It's one thing to sit and talk about the nitrogen cycle, about how plants somehow biochemically convert it, but we get to see it with our own eyes. Nitrogen is an element that is recycled by bacteria. This is in your guided notes, right here. <Pointing to guided notes>Flowers: Do you remember talking about the Nitrogen cycle in another science class… Biology? I know we talked about it, the cycles of matter, when we did in the environmental science unit in biology, but it was really short.

Mrs. Flowers: So does everybody know where they're writing notes down in their guided notes? We're going to incorporate legumes and to understand that we're going to talk corn and soybeans because that's very common to the central Illinois area. It also involves animals because animals are going to consume nitrogen in the source of some other type of animal or plant material… and you guys need nitrogen as well, because animals need nitrogen. Animals excrete waste, which adds more nitrogen to the environment. A lot of that is broken down through the help of bacteria. Also, bacteria are found in the root nodules of a legume plant like a soybean crop. They also help to biochemically fix the nitrogen to put it back into the soil. As soon as it is in the soil just like a water cycle it will eventually go back up into the atmosphere through denitrification. This concept may be something you don't remember from bio.

Mrs. Flowers: So instead of me standing here lecturing for an entire hour, because I know you love that, I came up with the way for you to try to understand the cycle first and put it in your own words first, before we start going through the notes. I think it's just one of those things that if you can kind of read about it, and understand it, that I think will be easier as a group to discuss it. So here is, it says on the top, "Ag Applications" and there's a website listed. There're questions that you are going to answer using that site. By answering these questions I think you will have a general understanding so we can finish these notes.

I think Mrs. Flowers demonstrates that she is familiar with her students' academic backgrounds, thus basing her instruction on students' needs, goals, and past experiences. In addition to BSAA, she teaches biology, and has previously had many of these students in her biology class. She told me she knows they have discussed this content in biology, and she uses this knowledge to guide her practice. Another way she bases her instruction on students' experiences is she uses examples that are relevant to her students: "We're going to incorporate legumes, and to better understand that we're going to talk corn and soybeans because that's very common to the central Illinois area."

Episode XI. In the following episode Mrs. Flowers is talking with one of her lower performing students about his long-term project. He appears to not know how to proceed. He tells her he wants to do something with plant growth. After discussing the topic for a minute Mrs. Flowers goes to a cabinet and grabs a bottle. Holding it out, she suggests a substance that might affect plant growth, and asks if he has heard of it before… *rooting hormone*. When he shakes his head, she says, “I am not sure, but I have *heard* it might affect the growth of plant roots. I don’t know if it works or not, but you can try it.” The student asks Mrs. Flowers about setting up his experiment, and then recalls he has a plant at home he might use:

S: How many do I have to grow?

Mrs. Flowers: Well, you would want to have a big control, but also a big group with the rooting hormone. Here's an example.

<Mrs. Flowers shows how to remove leaves from a stem and stick them in soil with hormone>

Mrs. Flowers: You rip off all the bottom leaves to expose the nodes, and these little nodes turn into roots, OK. So they advertise this in the market that if you go like this <sticking the stem into hormone> and then stick it into the soil, this is gonna’ root a whole lot faster than this guy, OK? So you would be researching whether or not there is any truth behind that. And then you'd research, like, what is in rooting hormone, like, what causes a plant to root, why does this speed it up?

Mrs. Flowers: So that's what you would be doing. If you want to use your plant from home, if you can figure out what variety it is... you may want to ask me to make sure what it is actually, because not every plant is going to be able to root really quickly.

S: All right.

Mrs. Flowers: For the amount of time I am giving you. I've got snake plant, English ivy, and this is a wandering Jew...

S: <Mumbles> I'll do those then.

Mrs. Flowers: This would be a really easy lab, but also a good one. Now that you know this, have your project proposal ready for tomorrow. Think of questions, research “rooting hormone”, you can also research “plant propagation...”

<Bell rings>

Mrs. Flowers seems to sense that the student is struggling with the assignment and leads him in the right direction. She does this by ‘introducing’ him to the existence of rooting hormone, but she does not outright tell him what it does exactly. She appears to be enabling the student to design a program of research that interests him and is about what he wants to know. The suggestion she makes is very applied and tangible, made in a manner accessible for the student. This could be taken as a demonstration of how she modifies instruction based on awareness of her students’ needs, goals, and past experiences.

Use of small-group and whole-class inquiry. Mrs. Flowers uses a lot of small-group work in her classroom, mostly in the form of experiments. After looking over her curriculum plans for the semester I noticed she had seven long-term labs scheduled. I asked her how she keeps everything on track with so much going on. She said it is not a problem for her, but the students are a little surprised. “A lot of times with plants, it takes like three weeks for something to germinate and grow. [The students] are like, ‘we're just gonna sit here?’ ‘No, we're not gonna sit here.’ So then we start a new lab, so we might have four, five, or six labs going in the greenhouse at one time. It keeps them busy, out of trouble.”

Episode XII. With every experiment Mrs. Flowers has her students write a collaborative lab report.

Mrs. Flowers: So how do we feel about that first lab report? You guys feeling OK about it?

S: Awesome!

S2: It wasn't as hard as I thought it would be.

Mrs. Flowers: OK. Was it kind of nice using Google Docs and working together?

<Multiple students answer, somewhat unenthusiastically> Yes.

Mrs. Flowers: Good, well, we'll probably stick to that format. I do have to say, based on what I saw yesterday, you were really working hard and it was nice to see you guys all kind of collaborating and working together. Did most of you guys use Google Docs, where you're able to share and fix each other's stuff?

<Students acknowledge using Google Docs, say they liked it>

Allowing students to work in small groups is a factor that promotes inquiry and student autonomy (NRC, 1996). Having her students use the collaborative function in Google Docs promotes and fosters collaboration.

Episode XIII. Mrs. Flowers says she wants her students to make their own decisions and work independently. She told her class, "You're going to be able to come up with an entire problem, test it, and experiment. The only thing I am going to tell you is that it has to be somehow related to organic and inorganic." Later in the week, Mrs. Flowers moved around the room meeting with groups to inquire of them how their research designs were proceeding:

S: So, we're going to have like, water plants, and we're going to put them in different types of water to see if they can determine like, how healthy the water is. We'll put the plants in like, drinking water, distilled water, dirty water with like algae in it.

Mrs. Flowers: What kind of plants are you going to use?

S: I don't know.

Mrs. Flowers: Are you talking about an actual plant that is supposed to live in the water?

S: Yeah.

Mrs. Flowers: OK, so, I guess my thought is, I don't have those, so you'll have to seek information as to where you can find that. So I understand you guys are thinking you are going to be determining the growth of that particular crop, you can definitely do that. Are you going to have some water testing kits available so you can test the different things in your water? Then you could have a bunch of science questions too that talk about water, and types of water, and what is distilled water vs. what is found in ponds. Call around to find those plants, where you can find to buy them, and keep me posted.

Mrs. Flowers asks another group how their research design is proceeding**:**

Mrs. Flowers: Hi!

S: It will be me, and this group. We want to compare different kinds of drinks, like energy drinks, Gatorade, water, things like that.

Mrs. Flowers: OK, so you're basically going to be using different types of liquids? So the first thing you want to do is figure out why each of these different liquids is good for your body. Like for Gatorade, you might want to study the electrolytes. If you think, "Perhaps what is good for your body, might be good for the plant?" You'll want to study what is in each liquid, why are energy drinks on the market? They are supposed to boost your energy. Will they boost the plant's energy? Make it grow faster? Cellular respiration, study that sort of stuff. You could even do something that is pretty high in sugar, talk about why sugar may be beneficial to plants. Does that sound good?

S: Yes

Mrs. Flowers: OK.

S: What should we use for, like, plants?

Mrs. Flowers: OK, plants, good call. I have tons of seeds... <tells them about seed options>

Her interaction with another group:

Mrs. Flowers: So, you're doing worm castings, like tea? And comparing it to liquid fertilizer? So I think your research problem can be, "Which is more beneficial to plant growth, organic or inorganic fertilizer?" Isn't that what you are doing, those two different kinds?

S: Well, we also have water, regular water.

Mrs. Flowers: Oh, or you can say, "Does fertilization help plant growth, and if so, would organic or inorganic be more beneficial?"

S: OK.

Mrs. Flowers: So that way, you're trying to figure out, "OK, water's bad, compared to the fertilizers." And then, you're also segregating the two [fertilizer treatments]. How's that? Does that make sense?

S: Good. Yes. Thanks.

Mrs. Flowers: Yeah, you're welcome.

And one more group:

S: We're going to put cut flowers into vases and then use different things to see which ones make it last the longest.

Mrs. Flowers: OK, so you're going to use different types of preservatives?

S: Yes.

Mrs. Flowers: Kind of, to see which ones are going to preserve the longest? OK, what I would do for that, is research a bunch of different kinds, see what people are using and have had results from. I've heard of Sprite, with the sugar... You could also get some floral preservative from a flower shop, since it's made especially for that. You could look at different preservatives, there's tons of different...I'm not going to tell you cause I don't want to tell you things that you could use, but, use several. I would use white carnations, they are easy, and cheap. I would make sure you have a pretty large test grid, like maybe three carnations at least, in each different solution you have. White carns will let you see burning of the leaves... For your science connections questions, you might see... 'Why do florists put that stuff in there?' It has to do with the fact that you've now cut the entire root system away from the plant, so you've really essentially killed your plant, now it is just a question of which one you can keep alive as long as possible. It's no longer going through photosynthesis, so if it can't make its own sugar how does it get its sugar? Well, it would get its sugar from you dipping it in a preservative...

Taken as a whole, these interactions with the small groups inform me that Mrs. Flowers is very engaged and attentive. She is attempting to guide her students in their projects. Episode XIII is a little mixed. She is giving them great autonomy, allowing them to select a project in which they are interested. I feel that while she tries to remain hands-off, she cannot help but intervene. This would seem to be at odds with her intention of letting them “make their own decisions and work independently,” and her statement: “The only thing I am going to tell you is that it has to be somehow related to organic and inorganic.”

Authentic and real-world problems. As mentioned above, a large component of Mrs. Flowers’ curriculum involves lab work. “For me it's a real-life thing, where you learn by doing something and it sticks. It's not like I'm walking out of your class and I don't remember what I learned.” She added, “I like to do and see to learn.” This preference seems to be reflected in her teaching. She says she likes taking the students out to the greenhouse to work with their hands, and as mentioned in episode XII, she commonly has her students running experiments.

Mrs. Flowers summary. In Mrs. Flowers’ instruction one can recognize instances of inquiry and also a great deal of non-inquiry. Her questioning techniques seem to ask for narrow definitions, and I observed that once they were provided she seemed to move on to her next point. This is similar to Mr. Green, but different than Mr. Black. Her students seem to be more engaged than Mr. Green’s, but compared to Mr. Black’s, I observed less of the puzzling and thinking that is apparent in his class. She does talk about letting her students have a great deal of freedom in her class, especially regarding their long-term project. Mrs. Flowers provides great latitude to her students, but it is bounded by expectations and structure in the form of detailed assignments, reinforced by her guiding input.

Mr. Wayne.

Teacher use of discourse that is conducive to inquiry, Instruction based on students’ needs, goals, and past experiences.

Episode XIV. On one occasion, I visited Mr. Wayne's class when they were studying semen motility. Mr. Wayne was preparing students for their lab activity:

> Mr. Wayne: Okey-dokey. Is there anybody that needs a copy of the lab? We're going to look at procedures, part one. Number one the reminder of part one is that you're not going to need a cover slip… Excuse me, I take that back, it *does* call for one cover slip. Here's something you weren't doing the other day that you need to do; you need to clean the cover slips, Okay? I have some paper that I will set out that you can use clean your slips so the first thing you'll need to do is clean off your cover slips. Somehow they got dusty in some way and I don't know how that happened, but you will need to clean the cover slips. So make a note that you will need to clean those off to get rid of the dust on those.
>
> Mr. Wayne: Another difference, there is no stain. There is a buffer, and you will look for the bottle that says "sodium citrate" and remember in part one we're just looking for the mass of sperm as they are moving around, we will be calculating that and recording that on our datasheet. Your data table is going to be the worksheet. Now, there isn't really anything… Oh! Well, let's see here. All right, one place that you will have to write, there is one column and box on number six, you have to estimate the percentage of motility of sperm. How do you do that? You just kind of guess. If they're all moving put "100%," if there's a few that aren't living, put "88%." It's about half of them put "50%." You get the idea for step six part one. The other thing is it says, "Use a small wooden stick to place a small amount of semen…" Replace that with, "Just put a drop using the pipette." You already did that the other day. Okay on part two, you're learning how to practice. One thing we did not do was take a lot of time to dry the slide, so you can dry stain quickly by

placing underneath the heat lamp, but you want the heat to get to it but you don't necessarily want to fry it. So just place it on the warm plate and kind of put a paper towel tent over it so that the heat gets through but the light does not. For part three you're going to use the same slide and that's a kind of, "One of these things is not like the other," scenario. In part four there's a new fluid. In it tells you want to do and you'll do nine drops of the solution. It calls for a Petri dish, I'll get the Petri dishes out, get those warming up. One drop of semen, you can get that through the pipettes. And I have the ruled microscope slides and I'll get out for you, I think I have five of those so, two of the groups will have to share. When you get to that point you'll have to wash it off and then reuse it for the poor semen sample. The boar semen sample's a little bit different, we have two sample types, the boar semen sample actually has not been frozen. It has been refrigerated. It was shipped to me yesterday and I have kept it refrigerated and then I have been warming it up. By the time I get done talking they should be woken up enough so they can be used. They actually use an "extender," they call it. When they "collect" the animal what they actually do is dilute the sperm sample down using an extender and what that will do is increase the number of doses that you can get from one collection of the animal. So there are some other fluids that they put in besides just the semen. They put some chemicals in there with the pig chemicals, they put an extender in, semen cells, the *sperm* cells, excuse me, and so we have to wake those up by using a warm water bath, which I've been doing as I've been talking, warming them up.

Mr. Wayne: Any questions on this?

<No response>

Mr. Wayne: Now, I will fully understand that today is difficult. I will fully understand that today requires some fairly advanced technical skill. I think that you were capable of mastering that skill however I want you to be confident that, you know, I am not here to… I realize that on Monday it was the first time that many of you have used a kind of microscope in a long time. I understand that is probably the first time really *any* of you have you used an oil immersion lens on a microscope, and so I get it. I'm not going to hammer you if there are things that we can't get done from the technical standpoint, know that I am here to be your technical support.

< Mr. Wayne continues discussing procedures, a student asks a question>

S: What is the difference between a regular microscope and an oil immersion microscope?

Mr. Wayne: Okay, on a dry microscope you've got a slide on the stage and we are looking at the specimen that's on the slide through the air. So, I've got my objective lens…

< Mr. Wayne draws diagram of lenses on chalkboard >

…this is a simple diagram. So this is the microscope stage, this is my specimen, you've got light coming up through there, I got my lenses there and my eyes right here. So there is a small gap of air in between the objective lens of the specimen.

S: I thought the problem with all microscopes is air?

Mr. Wayne: That's why I said on a *dry* microscope. There's a small gap there. Now, we don't think of this as a big deal… we'll get into another scientific question of "Why is the sky blue?" Well, the air actually bends the rays of light and you know, essentially, modifies the wavelengths to release different colors, which is why we have a change of colors in the sky at night. So, even though we never really notice it because right now I'm looking at Rachel's shirt, and Rachel looks like Rachel, and her shirt looks to me like it's purple, I don't really notice it. However if you did notice, what would happen if Rachel went over to the pool, and I'm standing about 10 or 15 feet away from her on the pool, and she just jumps in? Is it possible that her shirt is going to look to be a different color or different shape?

S: Yes!

Mr. Wayne: Yes. Why is that?

<No response>

Mr. Wayne: Well, the light rays are hitting the water from above from the lights in the ceiling about the pool, they are bending in the water. When they reach her shirt they are reflecting off her shirt and they are bending… in particular [they are bending] once they get to the barrier between the water and air. So the water is distorting my… the water changes my view. Now if I put goggles on and go underwater, I get a clear picture, which is where the oil immersion lens comes in. So what we'll do here with the oil immersion lens is we'll put a drop of oil on there, we are eliminating that air space between the lens and the specimen, and we are reducing light bending, and therefore we are able to get a clearer picture of what is going on in the specimen. So in the oil immersion lens the oil is modifying the properties of the light that is coming up through the specimen so that we can see more clearly… we hope.

In this episode it appears there is little use of discourse that is conducive to inquiry. Mr. Wayne's instructional style is similar to Mr. Green's instruction, in which he seems to move down the list of questions or issues to get to his point. He does well to use students and references familiar locations and concepts in his examples. His style is different from the instructional manner of Mr. Black, who pauses and engages the student to clarify the meanings of students' answers. It should be acknowledged that not all content must be expanded or dissected, but the difference in approach was noted.

Episode XV. Later during a class when the students were studying comparative reproductive anatomy in livestock, Mr. Wayne was preparing his students to start dissecting:

> Mr. Wayne: Now, you've handled other specimens, you've dissected your fetal pig, chicken wings, dissections are nothing new. We are also dealing with a sensitive area. We are dealing with the female reproductive system. You can understand a high school teacher going through the catalog in their mind of the things students could do wrong with this, or might be seen as disrespectful. But I am going to give you the responsibility by placing a tremendous amount of responsibility in your hands by giving you these specimens and giving you this dissection. Why? Because it's valuable to your learning, we're learning about animals. We need to manage animals, we have to manage their reproduction.
>
> Mr. Wayne: Some of you in here have stated that someday you might like to be a veterinarian, and if you're going to be a veterinarian you have to have knowledge of some of the places... some of you in here are in industry, are gonna' produce. And, the artificial insemination things are right up your wheelhouse. Some of you in here might get into the animal industry, some of you may not. But what I will guarantee you is a lot of you will have discussions about some of these parts we are going to identify with your physician in coming years. This will also make you a more knowledgeable consumer of medicine, so those are the three reasons why we take a look at these things. When my wife had a

baby, the doctor was actually sort of freaked out because she was talking about all these hormones and parts and things that were going on with the female reproductive system and I knew exactly what she was talking about. The doctor was like, ‘Oh wow, how do you know all this stuff?’ I told her, ‘I’m an ag teacher’. I, on a personal note, am very, very passionate about the stuff we are going to study over the next few weeks, because I think it is incredibly cool.

Mr. Wayne: Some of the things that you are able to do, in terms of reproduction with animals, are just phenomenal, there are so many weird things. You have the monotremes, like the duck billed platypus, that lays eggs, but actually has sweat glands in its belly that oozes milk.

S: Oh gross.

Mr. Wayne: Marsupials, have pouches, so they will give birth to babies that aren't fully developed, and they'll let babies have a hybrid childhood where they will spend part of the time back in the pouch, which is basically like a half-way house from the womb, which is bizarre. Marsupials also have uteri, which you are also going to look at today. Most of the uteri that we are looking at are Y shape. Marsupials have a uterus that is kind of shaped like a no smoking symbol. It's really weird.

Mr. Wayne: As you start to see some of these things, you'll understand. We're going to start to see three different species; we have pigs, we have sheep, we have cows. Different parts of the uterus are different sizes, and when you go to the doctor and see the little model of the human uterus, you'll notice that the human uterus looks completely different. We can start to identify some similarities and differences, and your activity actually has you doing that. Looking for similarities and differences between your species

> and the species that the other students are studying, and when we start to think about humans we start to get even crazier. So what I did here, just to start, I put an example of a bovine reproductive tract up on the board, and you can kind of see how the parts are laid out. We start by looking at the vulva, which is the external opening. I think you did this already on the activity, with the cartoon that you had to label. I think that would be helpful to you if you were able to pull that out and look at it. The bladder is going to look like this, and be very, very muscular. I think you are going to be surprised when you see the bladder, particularly the pig bladder. All the pig's organs are kind of similar in size to the human's organs. You see that bladder, you are going to think "Oh my goodness, *that's* all the bigger that is when I have to pee really bad?" The vagina and the cervix, and then we get into the uterine body. In the bovine, it has two large uterine horns, the fetus is carried in the uterine horn. In the human the fetus is carried in the uterine body. So, when we look at a human uterus, vs. a bovine uterus, we have some differences right off the bat. The body of the human uterus is really big compared to the horns, whereas the body of the bovine is really small compared to the uterine horns. I've given you some things to potentially look at.

This lesson consisted mostly of lecture, with two or three student comments. There appeared to be little opportunity for student input, and Mr. Wayne did not ask many questions of any consequence. From what I observed, this is normal for Mr. Wayne's classroom instruction. This instructional approach would not appear to be discourse that would be defined as being conducive to inquiry. On the other hand, Episode XV appears to be an example of instruction based on students' needs, goals, and past experiences. Mr. Wayne reflects on students' past experiences, reminding them of past dissections they have performed in class. He addresses the present, acknowledging that some students may be actively engaged in animal production, perhaps holding hourly jobs or raising their own animals at home. Mr. Wayne also addresses the future, acknowledging that some students have told him they want to be veterinarians and others may one day hold industry jobs. He seems to recognize, and relates to his students, that regardless of ties to agriculture, all of his students will be consumers of medicine in the future. This example may demonstrate how Mr. Wayne bases his instruction on students' needs, goals, and past experiences.

Mr. Wayne summary. I would describe Mr. Wayne's classroom discourse, lecture, and step-by-step lab worksheets as regimented. When I asked about his instructing his students to use Google to study anatomy, he told me he does not fully know anatomy yet. "I'm not that good at it." He notes that an advantage of inquiry-based instruction is that the teacher does have to know all potentially correct answers. I would add that a teacher *does* need to know how to facilitate learning and show know how to guide their students to sources of useful information during their inquiry (Thoron & Myers, 2011, p. 176), which in this episode Mr. Wayne did.

Out of Class Activities

An aspect of these teachers' instructional methods not discussed in depth thus far are the various activities, projects, and initiatives they pursue outside of school hours. Mrs. Flowers has students working on long-term projects. "Each semester [students] have to come up with their own unique science experiment. Along those lines I don't give them any rules other than 'Come up with a science experiment that deals with plants.' " She continues, "I would say that there is definitely some inquiry-based [instruction] there, and the kids getting to develop and actually critically thinking and putting it together, instead of me always, 'Do this, this is why we're doing this, now we're in a lab.' " Mr. Black uses a long-term project in his instruction. Mr. Wayne does not use one in BSAA, but does have students complete one in his Introduction to Agriculture class.

Next, I will address agriculture activities conducted outside of class time by students enrolled in agricultural education. One avenue for out-of-classroom experiences is the Supervised Agriculture Experience (SAE). SAEs are year-long projects during which student members of local FFA organizations plan and undertake a project of their choosing. An SAE may be raising livestock or crops on one's own farm. There are eight types of SAE projects, which include: entrepreneurship, placement, agriscience research, agricultural service learning, exploratory, improvement, supplemental, and directed school laboratory (FFA, 2014). SAE projects are often demonstrated at county and state fairs, in the form of showing livestock or displaying projects. The projects involve hands-on application of concepts and principles learned in the agricultural education classroom, with guidelines for the SAE projects governed by the national FFA organization (FFA, 2014). In essence, SAE is a high school agricultural education program approach to experiential learning.

Students in Mrs. Flowers' class participate in SAEs if they are members of the FFA program, but she does not supervise the students and is not their FFA advisor. Mr. Green's and Mr. Black's students that are FFA members also participate in SAEs, but again, not during the school day nor as a component of BSAA. Mr. Wayne believes so strongly in their value that he includes working on SAEs in his curriculum and mandates students' participation by allocating 10% of their grade to their SAE projects. In an interview he told me "one form of inquiry [learning] is the ill-structured problem." Continuing, he told me he includes the SAE in his curriculum because, "the ultimate ill-structured problem is the SAE."

The final out-of-class topic I want to address is something Mr. Green and his students are doing. Mr. Green told me:

> Our FFA chapter took an acre and has done a demonstration plot. We're gonna' plant our fall stuff, we're finishing our summer stuff, so it's all winding down, but we're going to plant our fall stuff here in the next week... we're doing all lettuce, and greens, and stuff like that this fall, and we're looking at this becoming a farm incubator kind of thing. We've got Farm Bureau looking to get, we'll get about 5 to 7 tenants of various sizes, and we'll have a food hub built into this incubator, so that we're able to tap into some of the commercial wholesale markets. We've had conversations with two distributers out of Chicago who are waiting on produce, essentially. "You guys produce it and pack it and we'll take it." The village has built... taken an old shop, called the Rantoul Business Center, where they actually do business incubators, but they have some space in there that it not used, and they built a cold storage facility, and they took some stainless steel equipment from the military base, when the kitchens were there, and so we have a food processing, food packaging, washing, cold storage facility.

This excerpt is relevant because it is an example of Mr. Green using activities that promote inquiry. Although not taught as a component of BSAA, students in his charge are practicing inquiry with this gardening enterprise. Mr. Green’s students are planning, prepping, planting, caring for and maintaining, harvesting, cleaning and packing, and shipping vegetable crops. They are involved in budgeting, advertising, laboring, and sales. This vertically integrated experience appears to be rich with opportunities for students to learn on their own and practice inquiry. Mr. Green told me he allows the students to decide what and when to plant, etc. Levels of freedom and self-determination are greater in this setting than in the classroom; perhaps Mr. Green has to manage fewer students in field work (therefore is able to relax and work closely with students), or perhaps he is more at ease/at home in the field as it closely relates to his background in specialty crop production and experiences growing up on his farm?

Summary

Discussed above are teachers' different approaches to instructional discourse and practice. The use of inquiry in these examples seems to be a continuum with Mr. Black at one end and Mr. Green at the other.

Mr. Black. In the group of four teachers I observed (excepting long-term projects), Mr. Black most often was observed using inquiry-based instruction. The other three teachers used some structured inquiry (such as students investigating a teacher-prepared question through a prescribed procedure, Banchi & Bell, 2008). Mr. Black's students, in discussing ideas in an open forum during class, are encouraged to question, posit, and collaborate among themselves. Their interplay relates what they already know about science and agriculture to what they are learning in class, which can help with discovery and understanding. When I asked Mr. Black if he uses principles of inquiry in his instruction he said the following:

> Yes, that is how I was trained. At the time I went through my undergrad the pedagogy that we were really focusing on was a problem solving inquiry-based approach. We talked about how we give students a problem and lead students through what they will need to know to find an answer. So I see a lot of direct links... and… that's my approach as I teach BSAA.
>
> My hope is that... well, number one, we're going to approach science differently. We're going to approach it [from] an inquiry-based, look at a problem and figure out why, or look at process and figure out how does it work, why does it work that way, using the

scientific method. What my goal through the class is that they are thinking and engaged cognitively and not simply memorizing facts and figures. Hopefully it will give what they memorized in biology some relevance to what they learned.

The BSAA content selected differs little among the teachers, but their approaches differ a great deal. As an example, some teachers may teach about the topic of chlorophyll by using questions in the following manner: “Class, there are five types of chlorophyll. There are the colors of each. Copy their chemical structures from the board. Can anyone tell me how they differ from each other?” A student answers the question. “Well done Jimmy. OK class, let’s move on to food transport in the plant…” Instead, Mr. Black allows three days for his students to come to understand on their own the differences in types of chlorophyll as he supports their inquiry. Mr. Black seems certain in his convictions, his methods appear to be intentional, and he says he has been trained in the practice of inquiry.

Mrs. Flowers. Mrs. Flowers and Mr. Wayne demonstrate similar principals of not telling students answers and having students look up information and work on their own. I observed both teachers using authentic, hands-on instructional labs. Although I saw both use aspects of inquiry in their classrooms, Mrs. Flowers perhaps involves her students more than Mr. Wayne from the beginning of the school year, as she includes her students in the decision-making process selecting most relevant labs. She also uses long-term projects in BSAA, something Mr. Wayne does not do. However, when I asked Mrs. Flowers about her use of inquiry, she seemed uncertain how to answer. Mrs. Flowers possesses some understanding of inquiry and includes measures of inquiry in her instruction.

Mr. Wayne. Mr. Wayne’s use of inquiry is difficult to classify. I observed Mr. Wayne using small group lab activities, which were appropriately challenging and related to advanced topics that are not normally covered in secondary classes (comparative reproductive physiology and semen motility). He appears to give students a great deal of autonomy in the lab, does not "stand over" the students as they work, and says he trusts they will be able to "handle it" on their own. I asked Mr. Wayne if his pre-service experiences had included instruction on the use of inquiry:

> No, and that was one of the things that's really, really tough, and it wasn't that I got to be CASE certified, and you start to go out to NAAE conferences, they start to talk about inquiry. And you bring little pieces back and you try it.

From my conversations with Mr. Wayne I get the sense that he possesses an inherent, realistic conception of what inquiry is, although until recently he had no formal experience with practicing inquiry.

Mr. Green. Mr. Green may sit furthest from Mr. Black on the spectrum of inquiry use. From what I observed, Mr. Green's instruction makes heavy use of lecture and asks simple and factual questions of his students, which garner few responses. When I asked Mr. Green about his use of inquiry, he said:

> As far as like, scientific understanding and inquiry, I hope that's what we're doing, cause that's my goal, is to teach them scientific inquiry.... you know, that kind of approach, I'm hoping that that translates that they do good in college, that they have a good understanding of scientific investigation, scientific inquiry.

This quote is similar, yet different to Mrs. Flowers. He says he is uncertain if he is using inquiry in his classroom. The difference is, he tells me he *intends* to use inquiry, but is unsure if he is, where Mrs. Flowers is unclear of the definition of inquiry but when told says that she does teach that way.

> The way I look at science and BSAA, is that if I can teach basic scientific inquiry, then I think I'm doing my job at least. It may not be... my job may not be necessarily to teach things like technical things and protozoa and everything like that, it's “Can I teach the students to ask questions and find answers in a scientific inquiry standpoint?” So we do a lot of labs that are based on principals of scientific inquiry. If I can teach the kids to do that at a high school level, I feel like I've done my job.

Mr. Green makes his uncertainty about inquiry-based instruction apparent. He wants to know about inquiry and acknowledges its importance, but he does not appear to use inquiry in his discourse, and he seems to use nothing beyond structured inquiry in his labs (Banchi & Bell, 2008). Mr. Green shares a sentiment with Mr. Wayne, relating to the challenge of getting students to use inquiry:

> That's tough enough as it is, I think, getting kids to ask questions, to figure out the answer, to lead them in further discussion, further inquiry. It's challenging. Most of these kids are programmed by teachers, myself included, to find answers, regurgitate answers, that's it. BSAA can't really be that class. There has to be scientific inquiry there, and that's hard.

Mr. Green says he *wants* students to understand inquiry, says he *thinks* he does uses it, says students should learn *how* to do inquiry, says he thinks he should use it *more often*, but is *uncertain* of how to implement it in his class. Mr. Green seems to possess some understanding of inquiry and includes measures of inquiry in his instruction.

CHAPTER FIVE: DISCUSSION

This chapter is divided into four sections. The first focuses on teachers' perceptions of the Biological Science Applications in Agriculture (BSAA) class and whether the science or agriculture content takes a front seat in importance. The second section examines the teachers' training and background in science. The third talks about teachers' informal experiences with science and scientific inquiry. The fourth section relates to teachers' conceptions of their practice and understanding of scientific inquiry (SI).

Teachers' Perceptions of BSAA and if Science or Agriculture Takes a Front Seat in Importance

Mr. Green shared why he likes BSAA:

> This class is important, it makes connections between things they may have learned in classes, learned at home, or in the world. Also for students that have a hard time in normal science, they struggle in biology or other science classes, (BSAA) allows them to make connections by seeing and touching. I have students that are interested in ag interested and some that just have a hard time with science. Some struggle in normal science classes, but in here just because of the tangible application of science, they enjoy it. The advantage of this class is that they can see, touch, feel, taste, and make connections that are more tangible.

Mr. Green appreciates the contextualization of science in agriculture and how the class supports students' making connections between their lived experiences and science. He appears to see value in providing students with alternatives for earning science credit and seems to credit the hands-on nature of the class as a reason BSAA makes science content approachable.

When Mr. Green was asked about whether the science or agriculture content is more important to him he said:

> It's very important that ag is in there, because it's an ag class. I want to… my main goal in BSAA is to teach agriculture and apply it to all the science. As much as they learn in biology and chemistry and physics, or whatever, however it applies. We teach some things that cross multiple sciences, it's not just biology. But my primary focus is the agriculture aspect of it, although I try to hammer home those basic scientific principals all the time, but the ag is first.

Mr. Green makes it clear that the focus of his BSAA class is "ag is first." He applies the agriculture content to "all the science," which contextualizes the science in ways students can better understand.

Mrs. Flowers shared her opinions with me:

> I think it's a really important part of giving them a choice of what science class to take and what life science class to take, and there are a lot of different learners out there and by offering different classes you're really differentiating learning and really giving them a choice. "Do I want to learn by hands-on or do I want to learn the way I don't learn?" And that way [I don't learn] is "here's information, memorize it."
>
> The fact that they get to see it, and they get to touch it, and "here it is, this is real life stuff." That's what's wonderful about the curriculum. That they are in the greenhouse planting and getting to see it with their own eyes is really cool and that's why I love the curriculum.
>
> I have students that this will be their very first ag class they have ever taken. They think of it as their science class, which I love, because I get to tie in all those ag concepts and

all of a sudden they get excited in agriculture, which is my passion. These kids are getting some real science knowledge out of the curriculum.

I just think it coincides with science so well, and I think that some of these students they go on to be in ag class, if they are taking the intro and ag business or whatever, and then all of a sudden they take this science class (BSAA) as well. All these concepts really intertwine; science, cells, photosynthesis, and cellular respiration, classification, and animal reproduction. All these different things can definitely be tied into agriculture. I think I just get them excited about agriculture, "Wow, agriculture really does surround us… I don't just have to be a farm kid."

Mrs. Flowers appreciates that BSAA provides her students with a choice of context in which to learn about science, an opinion she shares with Mr. Green. She repeatedly talks about BSAA being a hands-on class, which she says is “wonderful.” She also mentions the intertwining of the agriculture and science content as a benefit to her students; not only does it make the learning of science more applied, but it also serves to raise student awareness of agriculture today, a topic about which she is very passionate. Similar to Mr. Black, she seems to feel that BSAA makes connections to students’ lived experiences.

Regarding if she places a greater emphasis on science or agriculture:

I think it's 50/50. I try really hard to talk about the science concepts but then somehow tie it to agriculture. Those are my roots, and production agriculture is kind of the basis for everything, so, I always try to tie it back to agriculture and production or livestock, plants, or whatever. But I think the science concepts are really important too. I would definitely say it is a combo of both, I don't know if I would pick one over the other. I feel really strong about tying in science concepts into agriculture and then vice-versa. I just

> think they are both really important and they are definitely intertwined. I can't say that one is more important than the other. As far as BSAA goes, though, if you are going to get a science credit out of it, to me it probably needs to be taught by somebody that understands science, not just saying the word "photosynthesis" but actually explaining what that means.
>
> I think science is really important, almost as... I kind of feel like I hope there are... I can't really say, it would worry me if there was an ag teacher that didn't feel confident in science whatsoever teaching BSAA. I'd be like, "Ahhh! What are you doing?" It would make me nervous.

As she said previously, she is passionate about agriculture. Mrs. Flowers declares her roots are in agriculture but she feels a responsibility to focus on the science component of the class. Although she repeatedly says she cannot decide which is more important, it appears she may feel compelled by the science more so than by the agriculture. I surmise this because she said that if students are earning science credit for BSAA, the person teaching the “science” needs to have a strong “science” background. She reinforces this point by relating concerns she would have with a teacher not confident in his or her understanding of science teaching BSAA. Another example that may point to the idea that she considers herself a science teacher first is that she also told me that when the school faculty breaks into committees, she normally goes off with the science teachers. “I don't know if I consider myself... I consider myself an ag teacher, but I don't know... maybe more science than ag.” It would appear that science probably takes a front seat in Mrs. Flowers’ BSAA class.

Mr. Black related the benefits of BSAA and remarked how BSAA has changed agriculture education:

> Part of the difference, at least as I see it, is the development of these courses like BSAA. BSAA, the horticulture, and some of those specialized courses, I think have helped us as a profession. As I came through the ag program, as it was in high school it was "Ag 1, Ag 2, Ag 3, Ag 4." Everything was production based, production or mechanics, typically. That was my experience and I think that would be representative across the state at the time. And I think that there was a shift in who we were and what we wanted to be, and I think that the development of these types of courses have helped us move beyond just being a production-based approach to really start to move in, and broaden... and be more attractive to the non-farm students.

Mr. Black mentions a benefit of BSAA not mentioned by the other teachers; that BSAA has helped to keep agriculture education relevant. He reflects that as a youth his education focused on production agriculture, but that there is value in transitioning agriculture education to a more inclusive, post-production focus.

Mr. Black continues:

> The number one thing that I want students to come away with is to become thinkers and learners of science, not just memorizers of science. My hope is that, we're going to approach [science] differently. We're going to approach it in an inquiry-based, look at a problem and figure out why, or look at process and figure out how does it work, *why does it work that way*, using the scientific method. What my goal through the class is, that they are thinking and engaged cognitively and not simply memorizing facts and figures. Hopefully it will give what they memorized in biology some relevance to what they learned. The other thing I would say is, I don't have to know everything as a teacher and I have never pretend that I know everything. The inquiry model allows us to learn together

> and I'm a huge proponent of that. From day one, the problem solving approach, it allows us that opportunity to learn together with the students.

Here he says BSAA is an important class because it is conducive to students learning via inquiry-based methods. Like Mr. Green, he mentions how students benefit using a "figuring out why" approach to solving problems. Similar to Mrs. Flowers, he discounts the value of memorization next to critical thinking. Mr. Black mentions one of the benefits of his use of inquiry-based instruction in BSAA; he likes that he is able to learn *with* his students, which is a defined component of inquiry.

When asked if science takes a front seat in his class:

> With BSAA, students are getting science credit, so I feel a responsibility to teach science using agriculture as a contextual vehicle. That's a way to do that. If [universities are] going to recognize it as a lab science class it has to meet those standards, ideals.

It appears Mr. Black places science first. He too is acknowledging the value of contextualizing science in the agriculture content of BSAA. Like Mrs. Flowers, he says because BSAA students are earning science credit, the science should be featured prominently, referencing the university articulation as a motivating factor.

Mr. Wayne shares his opinions of the advantages of BSAA:

> They get to take the scientific method and apply it to something that is more than just individual concepts. The overarching goal is to build an understanding of processes of inquiry because most of the careers that are out there, involve synthesizing information, collecting information... so even if a student is going into a business pathway and they're going to be in marketing and sales, they're going to be working on collecting information and putting it into a form that's actually usable to them.

> The integration of science in BSAA is to start to prepare students for careers were whether they're doing research or they're taking research that's already out there and applying it into a career situation. The vernacular... you're starting to cross contexts a little bit, you're taking concepts that were almost exclusively the domain of the science teacher and you're putting it into a more applied and specific context.

Mr. Wayne seems to have a very practical and realistic opinion of BSAA. He says his overall goal is to instill in his students an understanding of inquiry. Like Mrs. Flowers and Mr. Black, he wants his students to be able to do more than just memorize facts. He wants them to think for themselves and know how to locate and synthesize information. He also mentions that BSAA helps students to contextualize scientific processes, a sentiment he shares with the other teachers. Further, he specifically mentions the value of integrating science into the curriculum so that students are better prepared for the world-of-work after they graduate. Similar to Mr. Black, Mr. Wayne sees value in preparing students to think about more than production agriculture.

> Teaching agriculture is my first, and you know obviously I'm not training students to go back and farm, 'cause you know, the opportunities to go back and farm are few and far between. What is the goal then? I always tell all of my students, "Less than 2% of the population will go back and farm, 100% of the population will be consumers of agricultural products." So what we try to do is make them educated consumers and try to get them to think clearly, and analyze the data that is out there**.** I don't really think about it that much, because it's really all together. You know, you're presenting... you're trying to get them to think about the agricultural context using a framework of the scientific method.

Mr. Wayne states that teaching agriculture is his first priority, a sentiment he shares with Mr. Green. This may not be a surprise given his very solid background in agriculture. He and Mrs. Flowers shared their conceptions of the intertwined nature of agriculture and science, and the value of the contextual nature of BSAA. Mr. Wayne later adds that instead of agriculture or science being his focus, his first priority may be to get his students to understand how to analyze and assimilate data and information.

In summary, all four teachers expressed they value contextualizing science in agriculture. Mr. Green, Mrs. Flowers, and Mr. Black said this context helps students to make connections to their lived experiences. This opportunity to approach science from a different direction is empowering to students according to Mr. Green and Mrs. Flowers.

The tangible hands-on nature of the curriculum is valuable as it allows students to learn and experience science via all their senses, according to Mr. Green and Mrs. Flowers. All but Mr. Green mentioned that having students engaged physically was more important than memorizing facts and formulae. All four teachers held strong opinions of whether science or agriculture is the focus of their instruction. Mr. Green and Mr. Wayne both said that agriculture is their first priority while Mr. Black and Mrs. Flowers seemed to say that science was first in their minds. Mrs. Flowers' comments were especially poignant, relating that she would be very worried and nervous for a teacher teaching BSAA that lacked a strong background in science.

Mrs. Flowers, and to an extent Mr. Black, mention that they value BSAA because it raises awareness of, and exposes students to agriculture. I perceive a difference between Mr. Green's, Mrs. Flowers', and Mr. Wayne's statements as they relate logic and emotion to the source, or motivation behind their statements. Mr. Green seems to use language that is more analytical in nature and makes a broad and definitive statement about the nature of agriculture,

“agriculture is science, it is what it is,” whereas Mrs. Flowers makes comments that stem from a more emotional connection she feels with agriculture, saying she “loves” the “wonderful” curriculum. Mr. Wayne’s thoughts seem to imply he has a more practical and realist conception of BSAA.

Both Mr. Wayne and Mr. Black mention inquiry as being an important component of BSAA. Mr. Wayne says he wants to instill an understanding of inquiry in his students while Mr. Black clearly states he uses an inquiry-based approach to instruction.

Pre-Service Training in Science

I asked the teachers what their backgrounds were in science, and if they had training in science pedagogy:

Mrs. Flowers

> No, not really. I just took science classes. No pedagogy to teach science, but lots of science classes. I ended up with 24 hours of extra biology when I graduated. I have a biology education endorsement and ag education endorsement.

Mr. Green

> I took a class called biotech in the classroom, and it was designed to integrate and teach new technologies of ag science in the classroom. We learned about GMO’s, biofuels, and new technologies… I took that at Clemson. It had a lab component, was mainly ag education students, and a couple of education students. Ag education 100, 200, 300, 400, especially at the 300-400 level… it was teaching science, well not exactly, but kinda’. My soils class was very heavy on chemistry, so that has really helped me a lot now when teaching these concepts… I can draw on it when teaching.

Mr. Wayne

> Basically I'm certified to be an agriculture teacher. A BS is 126 hours, I took 152 for my undergraduate. Most of that was in mechanization because that seemed to be where the market was for ag teachers at the time. You know, a lot of my training in 'agriscience' or 'integrating science' kinda' came on the fly, after I started, and that became a lot more formal when I started attending professional development through the national association of ag educators (IAVAT). But probably the biggest leap came when I started to get CASE certified in courses, and that started in 2011.

Mr. Black

> Well, that curriculum was developed at the U of I by my instructors at the time. It was in the development phase and as I was doing my undergrad it was really... they were promoting it, they were in the thick of it, in the writing of the curriculum. It was something we spent a fair amount of time on as undergrads. I also came out with a science endorsement. Then Illinois had a grad course on implementation and instruction of BSAA and PSAA, BSAA animal and BSAA plant, and PSAA as well. I was one course from a complete double major. At the time I went through my undergrad the pedagogy that we were really focusing on was a problem solving inquiry-based approach. So I see a lot of direct links... and that really I hope, that's my approach as I teach BSAA.

In summary, these quotes all relate in some part to the fields of science in which they took classes. Mr. Green said he had a number of classes that included science pedagogy, "well not exactly, but kinda." Mr. Wayne says most of his training in pedagogy came "on the fly" and only recently did he receive formal training in teaching science. Mr. Black related that his training was based on inquiry, in the form of the problem solving approach. These quotes appear to show the teachers all have strong backgrounds in science content, but aside from one class Mr.

Green had as an undergrad, only Mr. Black had been formally trained in scientific inquiry when they started teaching.

Informal Experiences with Science and Scientific Inquiry

Mr. Green talks about his experiences as a youth:

> Agriculture is science, it is what it is. It is a science and so when you have livestock, we had cattle for example, when you have cattle and a barn, and there is something wrong, you ask questions, "Let's figure out what the answer is..." so that kind of scientific inquiry was being developed (in me) by my father, who like I said, is not a scientist, he's a business person… So, scientific inquiry was being developed [in me] by working on the farm. For me when I was growing up… science classes were the ones I liked because of the hands on. I could see it, I could touch it, do it. Whereas in English class, I'm reading it, that bored me out of my mind, but as a student I needed to see, touch, and do, like science classes... no matter what the subject, no matter what we were studying, if I could see it, touch it, do it, I enjoyed that. And that was what ended up drawing me to ag science, whenever we had an ag program in high school, I loved agriculture because instead of reading about something we were actually doing it, and growing, and creating. So the *science* classes were the first ones to kind of introduce me to that. It's the first we did experiments in, the first we did those fun, hands-on activities, instead of reading or drawing. That was the class that hooked me, because of who I am as a person, and I think a lot of students are probably that way too. Our ag students are ones who want to "do," the ones that like ag, want to do something.

This passage relates to two possible facets of his identity, growing up on a farm, and his experiences in high school. In the first part of the passage, his statement, "Agriculture is science, it is what it is" seems to suggest that he thinks science is inherent in the space where one finds agriculture. It appears Mr. Green feels there is a strong connection between his lived experiences growing up on a farm and his conceptions of science; that the setting leads to connections being made between agriculture and science. In section one, when asked about the value of BSAA, he makes a similar comment, "this class is important, it makes connections between things they may have learned in classes, learned at home, or in the world." He may mean that there is something about an agriculture classroom and a traditional agriculture setting that aid conceptions of scientific inquiry. He reinforces this idea with his next statement about sick cattle when he mentions asking troubleshooting questions, "let's figure out what the problem is…" on the farm. Mr. Green tells us that this practice is "scientific inquiry." The *National Science Education Standards* (NRC, 1996) states that asking questions is a component of scientific inquiry.

In the second part of the passage Mr. Green describes how he was attracted to classes that were engaging and interactive. He recalls that science classes, where the lessons were hands-on, and he got to "see," "touch," and "do," served as a gateway to his enrolling in agriscience classes. He explains that this attraction is inherently due to who he is as a person, which could be construed as Mr. Green describing a facet of his identity.

Mr. Green also talks about his high school teachers as an influence:

> I would say my high school teachers were very good. I had a really excellent biology teacher and an amazing chemistry teacher. I struggled in high school chemistry but that struggle helped me so much when I got to college. I felt that college chemistry was a breeze compared to high school chemistry because I had an excellent teacher. Created good science habits, good habits when it comes to writing lab reports, things like that. I had great high school science teachers. I draw on what I learned in college, I had great

high school science teachers, and that helped with the understanding of what a high school science classroom should look like. I had an interest in science in high school so as a kid I liked science in high school, so that helps out. I would draw from that, and then you start teaching, and there's a lot of experiences you gain as teaching science in a high school, so experience helped out a ton... just doing it (science) is valuable.

My high school chemistry teacher was so meticulous with record keeping, and when we did a lab, just the way he... his lab reports were super interesting. We had to have one of those notebooks, composition notebooks, black ink pen, had to write in cursive, had to write in third person, past tense, the entire lab report. As a student I had no clue, never understood it, was frustrated by the whole, "Has to be this, this, this, this, this." It didn't make any sense, but it was the rules, it was his expectations, so you met it. He taught you how to write a correct lab report, what you should include, but it was all those little details. Well, when I go to college and I wrote my first lab report... number one, they didn't teach you how to write a lab report in class, biology 101 or whatever, they never taught us... and I'm getting excellent scores on my lab reports and they're asking me, "Who taught you how to write a lab report?" Whenever I had those college instructors ask me who taught me how to write a lab report it gave me some instant accreditation by validating what he was saying, so I remember, "Ooh, OK. This must be right and correct." So those details, like seeing the attention to details, whenever you start learning about science and scientific research, you know that those details are very important. Those two traits of my chemistry and biology teacher in high school makes me think, "OK, those were really good teachers." I didn't know it at the time, though. As a high

> schooler I had no clue it was really good science teaching. It took me becoming a science teacher to figure that out.

Mr. Green relates that his high school years had a great influence on his identity and understanding of science. He said he had very good teachers, and they created in him "good science habits." He reports he feels a good deal of his knowledge of science, and how science is taught in the classroom, came from his experiences in high school. Some of the examples he provides of the knowledge of science developed in him include accurate record keeping, organizational skills, and the ability to write good lab reports.

Mrs. Flowers shared her high school experiences:

> I took every ag class that I could possibly take in high school, and really fell in love with science probably because of my science teacher, he was a huge contributor... I just liked school, I don't know [smiling], I loved school, I loved doing homework. Is that weird? [smile] When I was able to move here, I was in my dream job, teaching biology and BSAA classes.
>
> I just was never one that loved to have somebody give me a bunch of information and just sit there, go home and study it and memorize it and then do well on a multiple choice test. For me, I loved BSAA because it was all hands on, and then we got to write about what we learned and what we understood. It wasn't, to me, it was so much more hands on, and that's how I learn, so that's why I like teaching it, because... no offense, but next door our biology teacher, she's outstanding, she's a great teacher, but she teaches anatomy and physiology, and there is just so memorization and just regurgitating that, and the next day on the test, and going through the muscles and all that, and I just... this is just different.

Like Mr. Green, it appears Mrs. Flowers was influenced by the high school agriculture and science classes she took. She says she fell in love with the hands-on nature of her agriculture and science classes, and in this passage, as in other instances in her interview, she talks about loving to "do" things, whether they be labs, activities, or homework. She relates that the inherit way she learns is hands-on, by doing and touching, not by reading and memorizing. This parallels what Mr. Green said, "I loved agriculture because instead of reading about something we were actually doing it."

Mr. Black's informal experiences with inquiry:

> Was I [learning via scientific inquiry] in high school? In high school it was not that way, and if you go down to the biology and physics wing today [in this building], you're not going to see it either. You'll see lecture, discussion, lecture, discussion… wait, no actually, lecture lecture lecture lecture lecture, maybe a lab, lecture lecture lecture lecture, maybe a lab. And that's what you are going to find. And the research suggests that that is a poor way for student learning and retention.

Mr. Black did not mention in his interview ways science was instilled in him in high school, but he did identify ways science was *not* instilled in him, referencing the traditional manner by which he was taught. Mr. Black points out a systemic problem with the traditional science education system as it is typically practiced, that it does not promote student learning and retention (Bednarz et al., 2006). He says that this is the way science is still taught today in many places, including his own school, and he feels this is a problem. Mr. Black continues:

> My cooperating teacher was a scientist. He was an ag teacher, but he was a scientist. In fact, when I did my student teaching he told me, "When you get ready to do your masters, don't do it in ag ed. Do it in a technical subject. Do it in agronomy, do it in something that

gives you technical skills... learn the science, so that you can teach it." That was something that I espoused. If I am going to be teaching science, I need to understand science. BSAA becomes just another ag class without the science focus.

He describes his cooperating agriculture teacher both as an “ag teacher” and as a “scientist,” who prompted him to earn his masters in a technical major, with the goal of learning the science so that he could teach the science. He concludes by reinforcing the importance of BSAA teachers understanding science.

Mr. Wayne was telling me about his childhood. I asked him if he felt he grew up around science or if the topic of science ever came up in family conversations?

> As far my experiences growing up, no. You know, the scientific method was not necessarily overtly discussed. My dad liked to fix things, he liked to work on things. I was curious about things. Once in a while I got to play around in the shop or whatever... and curiosity is kind of where everything starts but that was not really formalized until I started with, you know, essentially my junior high and high school years, you know, being able to try new things and tinker a little bit more.
>
> One thing I left out was we had junior high ag classes. They had… a rotation for junior high students where you did ag and industrial arts, and then family and consumer sciences. Then in high school I enrolled in intro to ag, was a student for four years, FFA member for four years, was a state FFA officer. My [high school] SAE project was, I had a corn and soybean plot. I started with 4.5 acres of each, and grew to 10 acres of each, and I would go and scout those and basically make decisions on every aspect of the project...

> I consider myself to be better in the physical sciences, namely physics, but I also... I really didn't take an interest in animals until I started teaching it. I was really more interested in physical science and physics. I remember doing very well in physics in high school.

Mr. Wayne mentions tinkering as a boy. Tinkering has been described in literature as informal experiences with common experimental materials (Parsons, 1995) and as an informal method of problem solving (Krieger, Allen, & Rawn, 2015). From what he told me, it seems Mr. Wayne has had some exposure to a form of scientific inquiry by way of the exploration and experimentation common to tinkering.

Although he said that science was not talked about around the house, Mr. Wayne's experiences with high school agriculture and FFA were apparently influential and would seem to be experiences that could promote knowledge of inquiry. His mention of his high school SAE project especially stands out, as we read in Mr. Wayne's earlier quote that an SAE is "the ultimate ill-structured problem." He said he was making decisions on every aspect of the project. Common activities students engage in during SAEs include reviewing what is known in literature, planning experiments, proposing predictions, using tools to gather, analyze, and interpret data, and using critical and logical thinking. These are activities that promote knowledge of scientific inquiry as described in the National Science Education Standards (NRC, 1996).

In summary, all four teachers shared examples of influential high school experiences related to science. Mr. Green and Mrs. Flowers were drawn to the hands-on "doing" nature of their agriculture and science classes, with Mrs. Flowers expressing, "that's how I learn." Both expressed a dislike of memorizing, which was another reason they gravitated to these classes.

Mrs. Flowers says she “fell in love” with her classes because of the context and her excellent teachers. Mr. Green says he had excellent teachers as well, and he says they taught him what good science teaching looks like. The things that Mrs. Flowers and Mr. Green mentioned they liked about high school science were absent from Mr. Black’s experience. He does not credit his high school science teachers with teaching him about SI. He says that his experience with lecture-based instruction was the antithesis of inquiry. It was not until he was a university student that he learned about the problem-solving approach. He credits his cooperating teacher with steering him in the right direction related to teaching science, and says he believes that if one is going to teach a science class one needs to understand science.

Two of the teachers said they believe they were exposed to principles of inquiry informally as youths. Mr. Wayne believes he was informally engaged in inquiry with his dad in the shop, but said that it wasn’t until high school that he really became engaged with science. Mr. Green credited his life on a farm for instilling in him a sense of inquiry and an understanding of science.

Conceptions of Their Practice and Understanding of Scientific Inquiry

In my study I sought to gain insight into the implementation of scientific inquiry in an agriscience classroom. This would include implicit views and conceptions of science held by teachers. I asked Mr. Black about how science is portrayed in his classroom and his perceptions of his students' abilities to learn science:

> Students can recite the scientific method but they cannot use it. Typically, they have limited experience with the scientific method, so I spend a couple of weeks talking through the scientific method and do some practice. We spend a fair amount of time differentiating between independent and dependent variables and what does a control

> look like. Often they think a control is something that is not treated and that's all. Whereas scientific control goes beyond something that is not treated, maintaining everything constant except the independent variable. So we talk about that. I spend a fair amount of time helping students... and then the other thing is differentiating between deriving their data and observations versus conclusions. Differentiating between those two concepts is particularly difficult for students. That is what we find is difficult for students. And then I do spend a fair amount of time helping kids identify sources of information, background of information, sources in literature, sources that are reliable. And then a couple of years ago I had to teach them how to write lab reports, how to cite sources, how to use information from sources without plagiarizing. "We've never had a research paper to do." The freshman English curriculum does very little research-based writing, so it was a challenge.

Mr. Black talks about challenges he faces in BSAA. Many of the things he talks about, teaching his students to identify sources of information, designing an experiment, collecting data, and communicating results, align with evidence of engagement in scientific inquiry as detailed by the NRC (1996). When he mentioned using the scientific method in class I asked him how he defines “scientific method.”

> When I present a problem typically what happens is I present them with a research problem, either in pairs or small groups. Students will devise an experiment to test some hypothesis. They'll do some background research to create a hypothesis. Formulate an experimental design with controls and independent and dependent variables. Typically do some sort of peer review with students, and then conduct the experiment, collect data,

> analyze, and draw some sort of conclusions, and then compare those back to what research indicated what should happen.

His response shares many of the same characteristics as his previous response. Although the steps he lists, problem, hypothesis, question, experiment, collect and analyze data, form and report conclusions, and reflect, are those commonly comprising the "scientific method," it would appear that as an example of a learning activity it would also serve to promote student inquiry.

In a similar vein, I asked Mr. Black what student would be the ideal receiver of science instruction if he could have a prototypical student. He replied, "anyone that walks through the door. To me, I don't have... ideally in the class I would have a mix of students that have backgrounds [in agriculture] but also understand the process of scientific method and inquiry." I interpret this to mean that Mr. Black wants his students to have a solid background in the methodological approaches used to study the natural world (scientific method) and to be familiar with and comfortable learning in an SI environment. I believe he understands the value of scientific processes and how they are components of scientific inquiry.

Following up, I asked Mr. Black if there is there is a need to differentiate science instruction between his students that come from traditional agriculture backgrounds and his students that come from non-agriculture backgrounds.

> Differentiate the science? No, because the process is the process. When I am teaching, as I look at BSAA, and look at the science, I really am concerned with the process and outcome rather than memorizing content. To me it's about the how and the why rather than what. To me I really don't see a difference there.

Research in science education suggests a link between teachers' views of scientific knowledge and their classroom practice (Brickhouse, 1990). In this quote, by saying he wants students to be able to think and question and to learn more than facts.

Mrs. Flowers was describing her practice to me. I asked her if she uses inquiry-based instruction with her students. She was uncertain, but said:

> Uh yeah…I try to do that. One [lab] coming up here next week, we're going to talk a little bit about different ways to produce food. We're going to tie in organic and inorganic, and I'm going to let them run through the steps of the scientific method and get into groups and come up with their own independent and dependent variables and what they are going to do is... I'm going to supply some supplies... they can plant whatever they want, but they have to come up with materials as far as what they are going to plant. I'll give them choices, such as "Here's some Miracle Grow, here's some N,P, and K over here, here's some worm castings, so that is organic, and here would be some fish emulsion… Right now we are talking about designing and conducting agriculture research, and the lab that goes along with it is where they are soaking seeds in aspirin and then soaking seeds in water and then we're seeing which one will sprout faster. Along with that we're going into, "Why is research needed in agriculture?" Because we're losing farmland but we have a growing population. On top of it we talk about the steps of the scientific method, and independent and dependent variables, and that kind of stuff... but the point being [hands me a copy of a lab] this ag applications page, this ties in to how science and ag relate, in my mind, so they've done a great job with the curriculum, I think, of telling you "This is how it relates and this is how it's connected" and these science connections questions are what I always lecture.

In response to my asking her about using inquiry-based instruction, Mrs. Flowers talked a great deal about teaching the scientific method. The following is an excerpt from one of her classes.

> Mrs. Flowers: Yes, this is real, this is real stuff. These are like, from credible sources. I know I kinda' lied to you last time, so "if you are interested in reducing your dependence on chemicals, lowering the cost of production, and increasing yields, then you need to use this stuff." Now that's a little bit opinion-based, right? But is it something we could probably test using the steps of the scientific method?
>
> S: Yes.
>
> Mrs. Flowers: Yeah. And who can tell me once again, what are the steps of the scientific method? Somebody raise your hand and tell me the steps. Or at least how about step one?
>
> S: State the problem.
>
> Mrs. Flowers: OK, state the problem. So, could we come up with a problem? How could we maybe come up with a problem for this?
>
> S: You can see, well you can... Ohhh, I don't know!
>
> Mrs. Flowers: No, you're doing great!
>
> S: ...maybe like, the inorganic stuff isn't good for the soil.
>
> Mrs. Flowers: OK, good, so. Could we test whether or not organic or inorganic is better for the environment? Or, more beneficial for plant growth? So, that could be a problem, right? So could you test that?
>
> S: Yes
>
> Mrs. Flowers: Very good, what's the second step? Yes, Stevie?
>
> S: Research your data.

Mrs. Flowers: Research your data. So can I go and find information about organic and inorganic fertilizer and figure out which one is best. Yeah, I could do that. So what's the third step? You guys can just say it.

S: Hypothesis...

Mrs. Flowers: Hypothesis, very good. So could I hypothesize that maybe organic fertilizer is more beneficial than inorganic? Maybe I could say something like, if I plant my seeds and use organic fertilizer, then it will... derive, or something like that. I could do that. How about the next step?

S: Experiment?

Mrs. Flowers: Good, I can experiment. What are the things I learned about experiment? How can I set this up, what are some things that are important when we design an experiment? Evan?

S: Dependent and independent variables?

Mrs. Flowers: Good, it has to have a dependent variable, which is what you are going to take data on. It has to have an independent variable, which is that thing that you expect will change the dependent. Good. You can only have that one. What else?

S: It has to be a controlled experiment so all factors besides *that* one are the same.

Mrs. Flowers: Good! It has to be a controlled experiment so if we're running this out in the greenhouse, which we are, temperature has to be the same, water has to be the same, light has to be the same, seeds... everything has to be consistent except for the fact that you're probably using organic and inorganic to try to test this and see which one is better, right? Excellent! And then, what do we do last?

Mrs. Flowers: What's the very last thing?

> S: Collect data.
>
> Mrs. Flowers: Well, kinda the last thing, we kinda compile two into one. But, we collect data, good. So we can record and figure out which one is going to thrive... and we can measure growth, and amount of growth, and see which one is best. And then in turn we can get a conclusion, right? So, we know this already, we know the steps for the scientific method. You're going to do just this. You're going to be able to come up with an entire problem, test it, and experiment. The only thing I am going to tell you is that it has to be somehow related to organic and inorganic.

While it appears her outward understanding of inquiry is uncertain, and she appears to focus on her use of the scientific method, she provides some insights into her *unseen* understanding of SI. Mrs. Flowers is very flexible. She has her students work in groups and provides them with choices "they can plant whatever they want." She acknowledges a social aspect to scientific research, contextualizing the need for research by addressing the challenges of increasing population and the loss of arable land. She also says the proscribed curriculum does a good job of making connections between students lived experiences and what they need to know.

I asked Mr. Wayne about his use of inquiry-based instruction. He provides perhaps the most overt, and salient understanding of the four teachers. After he says, "My ultimate goal is to build understanding of inquiry in my students," he addresses the educational system:

> We talk about, you know, wanting to develop inquiry... well, we've spent years and years and years and years of quashing inquiry. "Johnny, you're asking too many questions. Be quiet." "Johnny, you're talking too much, be quiet." You know, you're gonna' sit in rows, you're gonna' find the answer in the back of the book. If it's not in the back of the book it's wrong. Perhaps the hardest concept, one of the hardest things to change with students,

> this perception that there has to be a right or wrong answer. There can be multiple answers to a situation, and our systems is designed so that you have to get the right one. Well, there could be five answers to any given situation. You have to get them to open up their minds to the fact that things could always look different. They want to see things that look the same, they want the right answer. I tell them, "I will not give you the answers."

There are other challenges he sees with using inquiry-based instruction. "Inquiry must be systematic, it cannot be cobbled together. My students are too concrete. It's hard to get them to assimilate information and think for themselves, which are my goals. My identity should be that of a facilitator and guide, the students need to take the lead in learning." This is a very pragmatic and realistic approach to instruction and I think it is a reflection of Mr. Wayne's opinions and personality.

Mr. Wayne follows up on his ideas of his students' responsibilities. He feels it is the students' responsibility to monitor and stay on top of their own work, or they suffer the consequences. "In the real world most of the time, it's 'can you do it or can't yah?' and your promotions are gonna' be based on how well you do it. Whether or not you keep your job is going to be determined on, can you do it or can't you?" Curious about how this point of view influences his curricular decisions, I asked Mr. Wayne if he felt he possessed a professional identity as a teacher.

> Well... yeah, you know, I take stuff like that as kinda' of a buzzword. My identity should be to be a facilitator and a guide. When they walk in I want the students to take the lead with their learning. I'm gonna' provide them the pathway and the set up and the technical support and then I'm gonna' hope that they take things and start to run with them.

From what I have experienced in his classroom, these frank comments are typical for Mr. Wayne. I would describe as an opinionated and grounded teacher who is certain in his ideals.

Following are other examples of Mr. Wayne's instruction:

Mr. Wayne: Most of you are doing a good job of being careful and conscientious with what you are doing. You're not going to recognize everything you see, that's not our purpose. This is kind of a 10,000-foot view of the reproductive systems. We'll hopefully get this finished up by Friday.

Mr. Wayne: I don't see a scenario where I sit at the front of the class giving you answers, but I do foresee allowing each of you to ask 2-3 questions.

Mr. Wayne: OK, I'm going to do something I almost never do… I am going to give you some notes.

Mr. Wayne: I will set you up to succeed, but I am not going to tell you the answers.

Mr. Wayne: I know today is difficult, I think all of you are capable. I know this is the first time all of you have used an oil immersion lens. I get that, I'm here to be a technical support for you.

Mr. Wayne: If you want my assistance I am happy to help you with this.

Mr. Wayne: You’re gonna’ make mistakes. That’s OK.

On these occasions Mr. Wayne makes comments that suggest he is familiar with using inquiry-based instruction. Mr. Wayne indicates to his students that he will not *give* them answers but he is ready to support and assist, leading and guiding them to answers, hallmarks of the teacher’s role in inquiry-based instruction. This would seem to align with Doolittle and Camp (2003), “teachers should act as guide/facilitator, not conveyor of knowledge” (p.270). In this way, Mr. Wayne is similar to Mr. Black and Mrs. Flowers, who made similar comments to their students.

I asked Mr. Green about how he includes science in his curriculum:

> You know, no one has ever sat me down and said, "This is what BSAA should be," I've had to glean information from textbooks. Listen to other people talk about the class. What I, the way I look at science and BSAA, is that if I can teach basic scientific inquiry, then I think I'm doing my job at least. It may not be... my job may not be, my job is not necessarily to teach things like technical things and protozoa and everything like that, it's "can I teach the students to ask questions and find answers in a scientific inquiry standpoint." So we do a lot of labs that are based on principals on scientific inquiry. If I can teach the kids to do that at a high school level, I feel like I've done my job. You've got to train them, and that takes time to train them to even think that way. And you've got to help them practice that, and that's challenging.

Mr. Green appears to understand that inquiry includes teaching students how to ask questions and seek answers. He says his job, in part, is to instill this understanding in his students and uses labs and instruction to do so.

Summary

All four teachers said they value the contextualization of science in agriculture and that the agricultural context of BSAA is a good one in which to learn science. Another aspect of BSAA they liked was that of the sensory connections that are made in agriscience. All four teachers talked about the advantages of students being able to touch, feel, and see. One other positive aspect of BSAA was the opportunity to raise awareness of agriculture topics in students. The teachers were divided on whether science or agriculture takes a front seat in their instruction with Mr. Black and Mrs. Flowers saying that science content is of greater importance that agriculture content to them in their classroom.

All four completed degrees in the agriculture sciences and appear to possess strong backgrounds in science content, but only Mr. Black had been formally trained in scientific inquiry. As stated earlier, Mr. Black’s preservice training was centered on the problem solving approach, which calls for placing the responsibility for learning on the student and encourages the teacher to assume the role of coach, or facilitator. All four teachers experienced agriculture through their childhood, living on farms, and the topic of informal exposure to inquiry, in the form of “growing up on and around a farm” and “tinkering in the shop,” was mentioned. Two of the teachers said that as youth they were strongly drawn to hands-on activities and classes based on their preferences for tangible, applied learning.

Teachers’ stated understanding of scientific inquiry varied from uncertain to proficient. Three teachers mentioned the challenges associated with using inquiry-based instruction, three explicitly mentioned as one of their goals to instill an understanding of inquiry in their students, and three mentioned the scientific method when prompted to discuss their use of scientific inquiry.

CHAPTER SIX: ASSERTIONS, CONCLUSIONS, AND IMPLICATIONS

In this chapter, I present assertions based on the episodes presented in Chapter 4 and the interviews in Chapter 5. The assertions describe themes related to teachers' interpretation and practice of BSAA and are organized around the research questions that guided my study.

Research Questions and Assertions

My overarching research question sought to describe and explore how a sample of BSAA teachers interpret and practice BSAA curriculum. It was supported by the following sub-questions:

1. What does BSAA teaching look like in practice?
2. How do teachers perceive their teaching of BSAA curriculum?
3. What role does inquiry play in BSAA classes?
4. Do teachers' practice and perceptions align?
5. How are science and agriculture blended in BSAA? On what do teachers base this decision?

Research question #1: What does BSAA teaching look like in practice?

Research question one sought to describe BSAA instruction. I saw passionate and thoughtful teachers that were intentional in their practices. I saw teachers of BSAA leading students in explorations of what they self-described as science contextualized in agriculture. I saw various instructional practices implemented including lecture, class discussion, laboratory experiments, small group work, research projects, greenhouse projects, hands-on projects in-class and out of class, etc. Teachers used a mixture of traditional instruction, problem-based learning, scientific inquiry, and collaborative learning.

I saw that at times students appeared bored, were not engaged, or were sleeping, and at other times students were very engaged, participating in group activities, critical thinking, and poignant discussion. In the group of four teachers I observed, their practices were at times comparable, and at others, dissimilar. Their use of inquiry-based instruction ranged from constant and proficient to absent. Some used a great deal of traditional lecture, and all used hands-on activities to some degree. Research and long-term projects were used as well as out-of-class activities such as SAEs and a vegetable production project.

Research question #2: How do teachers perceive their teaching of the BSAA curriculum?

Research question two sought to determine how teachers perceived their teaching of BSAA. The teachers told me about values, competencies, training and experiences, and the challenges they face in instruction.

All four teachers said they value the agricultural context of BSAA, and that this context is a good one in which to teach science. Mrs. Flowers went so far as to describe this aspect of the course as “wonderful.” They mentioned the advantage of students being able to form tangible sensory connections with the curriculum; all four teachers talked about the advantages of students being able to engage in activities using all of their senses.

Generally the teachers said they possessed adequate knowledge of science content to feel comfortable teaching BSAA, all having completed degrees in the agricultural sciences. Teachers’ self-described understanding of scientific inquiry ranged from uncertain to proficient. Of the four, only Mr. Black said he had received formal training in using scientific inquiry (in the form of problem solving approach). All four teachers grew up on or around farms, and the topic of informal exposures to scientific inquiry arose during interviews. Two teachers mentioned being exposed to scientific inquiry “growing up on and around a farm” or “tinkering in the shop.” All four teachers mentioned that their high school experiences with science were influential. Two teachers spoke about being strongly drawn to the "hands-on doing" aspect of their high school science and agriculture classes, and Mrs. Flowers added, "that's how I learn," meaning that she feels she learns best by being able to tangibly interact with what she is learning. Mr. Black, alone, mentioned his high school years as a negative experience with regards to science instruction, further reflecting that this negative experience perhaps influences his belief system as a teacher today.

Research question #3: What role does inquiry play in BSAA classes?

Three teachers mentioned challenges associated with using inquiry-based instruction. Three teachers explicitly mentioned instilling an understanding of inquiry in their students as one of their goals. Teachers asserted to various degrees that they used inquiry-based instruction in their classrooms. While evidence of inquiry was not evident in much of the instruction I witnessed, I think inquiry played an effective role in the classes where it was used.

Inquiry. Three teachers mentioned the scientific method when prompted to discuss their use of scientific inquiry. I think it may not matter whether or not teachers use inquiry or if they *say* they use inquiry and don't actually use it. It may not matter due to the messiness of inquiry. What interests me is how they *think* about inquiry. Do they think that "inquiry is science" or "inquiry is agriculture," or do they use the word 'inquiry' to prop up what they are doing in class?

***The messiness of inquiry*.** Inquiry has various meanings and is defined and practiced in many ways. Because of this ambiguity I think one can use any number of methods or activities and justify one's choice by saying "inquiry." I think one can make the case these teachers are using the messiness of the convergence of agriculture and science to do what they want to do.

I think the teachers in my study may use the term "inquiry" in response to my questions about their practice because they think it is what they are supposed to say. They may say it because I mentioned it, and they have keyed on that. They may have a misunderstanding (likely) of what inquiry is. As evidenced by their interviews, some may think that inquiry means using the scientific method, or asking students questions, or allowing students to conduct hands-on work and create research projects, or something else altogether.

This lack of understanding can lead to missed opportunities for effective instruction. In the case of Mr. Green, his minimal use of inquiry and use of a somewhat regimented teacher-directed learning experience is similar to a case examined by Baker et al. (2015) and Grady, Dolan, and Glasson (2010). In that case, the teacher in question expressed a sincere interest in using inquiry but "failed to execute it effectively" (Baker et al., 2015, p. 233), attending at best to the procedural steps of inquiry. This shortcoming was due in great part to his lack of pre-service and in-service experiences with using scientific inquiry.

Teachers will do what they want to do. Just as teachers use the convergence of agriculture and science to justify their actions, teachers can use BSAA standards to justify their actions. Experienced or savvy teachers know how to do this and will use it to include topics and activities they feel are relevant or justified; however, inexperienced teachers may also use the standards to justify what they teach. Teachers may say they are handcuffed by the standards, and are locked into teaching what they are required to teach, but this just means they are making a choice to follow the standards, whatever their motivations, thus justifying their choice. This may give teachers license to rush through lecture in order to cover their content. These teachers have a strong sense of what their students need and are attempting to teach to that end. All four teachers really seem to believe in what they are doing, and are certain in their actions, despite the differences in the appearance of their practices.

Their teaching is powerful because they are true to their own vision of teaching. When they exercise their power to be fantastic teachers and are true to their own belief system, their classroom practices really translate into sophisticated and smart science; they are using activities and labs that are legitimate, at times more complicated than those undertaken by their peers not in BSAA, and highly engaging.

Research question #4: Do teachers' practice and perceptions align?

Teachers' beliefs and attitudes influence the actions they take, their judgments, and their understandings. These influences are reflected "in their interactions with students, the strategies they use for instruction, their classroom management systems, their selection of what to teach, and their assessment and evaluation practices" (Jones & Carter, 2007, p. 291). Broadly speaking, these teachers sometimes do what they say they want to do and what they want, and then sometimes they do other things.

This leads to my theoretical frameworks, the Theory of Planned Behavior (Ajzen, 1991) and the Sociocultural Model of Embedded Belief Systems. The Theory of Planned Behavior describes an individual's intention to perform a given behavior as based on a series of influences (Ajzen, 1991). Intent indicates how hard people will try, or how much effort they plan to exert in order to perform this behavior (Ajzen, 1991). Factors that can lead to a reduction of motivation include lack of training or resources such as time, money, and skills (Ajzen, 1991).

My second conceptual framework is based on Sociocultural Model theory (Jones & Carter, 2007; Hutchins, 2009). This model references the teacher's sociocultural context as the environment in which the teacher operates (see Figure 2). Environmental factors can include the school or community culture, peers and administrators, and students and other stakeholders. Environmental responses to the teachers' instructional practices are filtered by the teacher's perceptual filter, which contains the teacher's belief system. This serves as a filter as the teacher engages in particular instructional practices. Experiences and feedback to their practice from the environment (peers, students, stakeholders, etc.) can lead to modifications of this belief system.

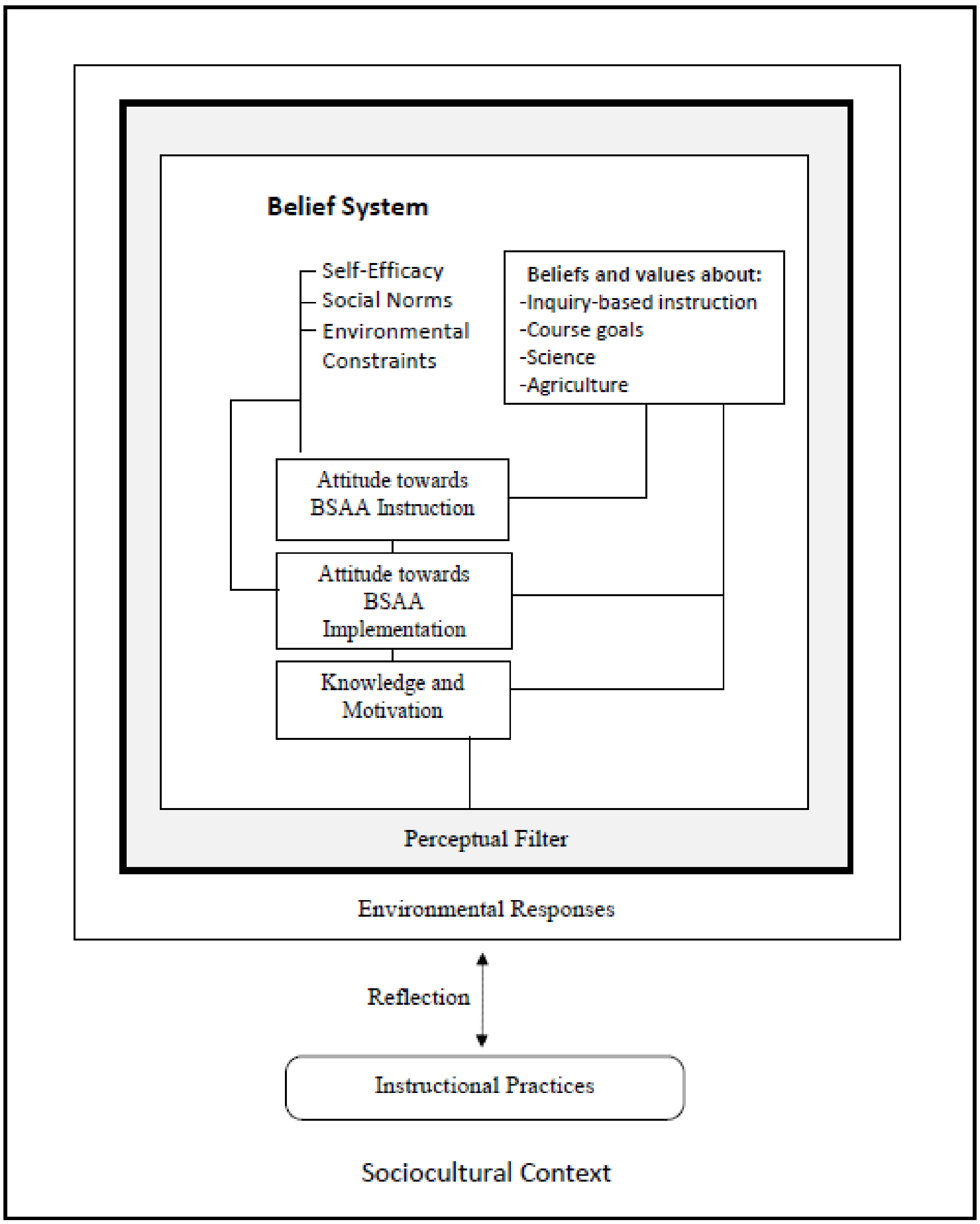

Figure 2. Sociocultural model of embedded belief systems

In my study I was specifically interested in teachers' beliefs and values about their course goals, science, and agriculture. As illustrated in Figure 2, these beliefs are connected to attitude towards BSAA instruction, attitude towards BSAA implementation, and knowledge and motivation. In the model, attitudes can be either positive or negative. For example, a teacher could have a positive attitude towards inquiry-based instructional methods, but a negative attitude towards actually using inquiry-based instruction in his own classroom. Knowledge and motivation refer to knowledge about a particular instructional practice and motivation to use the practice.

In my interpretation this theory suggests that when a teacher's belief system conflicts with the environmental response to their practice from the sociocultural context in which they are practicing, the result may be that the teacher experiences cognitive dissonance, which may manifest in a divergence from their intended action.

Cognitive dissonance. Teachers set goals and have aspirations, but may not be able to meet those goals and aspirations for a variety of reasons. When one's decisions or behaviors do not align with one's internal framework of goals, aspirations, beliefs, and values, one will experience cognitive dissonance (Myers, 1963). This dissonance may manifest, for example, when schisms between stated intent and actual behavior occur. A teacher may say, "I believe students need to learn organization, and how to be on task… these are really important things to me," but if the same teacher does not finish what they he or she want to finish or perhaps allows students to derail their class every day, they may experience dissonance; a teacher may say they want to use inquiry, but if he or she chooses lecture and "tells" students the material, he or she may experience dissonance. In the educational context of BSAA, I identified two broad kinds of tensions that may lead to dissonance, structural and philosophical tensions, as well as a coping strategy that teachers used to deal with possible tensions or dissonance.

Structural tensions. Structural tensions are schisms that may lead to dissonance for external reasons or reasons related to structure. Structural tensions contrast with philosophical tensions in that they are not related to an individual's beliefs or values, though they may have to do with an individual's knowledge or ability.

Limitations of teacher knowledge. Although a teacher's stated intentions or wishes are to use certain teaching methods, their competence with such methods may be lacking, resulting in an inability to use said methods. Their training in and understanding of scientific inquiry or SI, for example, inevitably influences what they do in class. This may be evidenced in what I saw with Mr. Green, where he said he really wanted to use inquiry but was not sure how to do so, so he was hesitant to try it.

Teacher competence with content knowledge. Teachers' competence and comfort with the curriculum can also influence their practice (Rudd & Hillison, 1995; Thompson & Balschweid, 1999; Knobloch & Ball, 2003). In my research, in several instances where a teacher was not familiar enough with particular topics they needed to teach. In some cases, teachers may avoid presenting topics with which they are not familiar. Mrs. Flowers told me, that when she was a new teacher, she did not know much about incubating and hatching chicks, so did not cover that unit when she first started teaching. On the other hand, as previously mentioned in my discussion of Mr. Wayne, despite his admission that he did not know much about the topic of comparative reproductive anatomy, he pressed forward and led his students in discovery.

Limits of instructional time. A common theme in teaching, multiple teachers mentioned the tension of instructional time limitations. Mr. Green and Mrs. Flowers said they were forced to select what they would and would not teach, because they could not cover all of their material. Some teachers feel they do not have enough time to cover their material, so they choose not to (Knobloch, 2008; Thompson & Balschweid, 1999). Teachers that are concerned with time limits, or covering content in the allotted time, may rush through the content covering it only with lecture, forgoing student-centered instructional methods such as inquiry, as I perceive in my observation of Mr. Green. However, some teachers reported that time was not a concern (Mr. Black).

When confronted with limitations in time, the teachers I observed adapted in two ways: They either rushed through in order to cover the content, or they covered only what time would allow. These two methods diverge regarding apparent thoughts on the topic of time, which relate to the richness, or depth and complexity, of instruction.

Mr. Green rushes through class content in order to meet time constraints. It appears to me that Mr. Green wants his students to focus on the facts. In one class period, he had his students go down the list of terms and topics from his review sheet, and although the students did not appear to be very engaged, he pressed forward. Later, during the same class period, he said to his students that he had a lot of content to cover and did not have time to mess around, reinforcing my belief that he was constrained by time.

Mr. Black appears to act as if time is of no consequence. To me, he seems to value the nuance and depth of topics more than teaching facts. When he recognizes a student’s misperception he pauses and first clarifies the student’s position before guiding the student toward cognition. Mr. Black told me he does not worry about the amount of time he spends on individual topics or whether he manages to teach everything he plans to teach. “I don't get too involved with that, it does not bother me. I am more concerned with what we do cover, are they actually getting, rather than looking, at some scope… I have identified what I think is most important, and move from there. If we get to all of it, fine. If we don't... fine.” This process takes more time, but Mr. Black seems to believe this is time well spent.

Student preparedness. Teachers also told me about problems with student preparedness. All four teachers mentioned that students are often not prepared to conduct research and write reports. This results in the teacher having to adjust their instruction to provide remedial or refresher instruction on relevant methods, or possibly not using those aspects of their instruction entirely.

Philosophical tensions. Philosophical tensions are schisms that may lead to dissonance for internal reasons or reasons related to one’s beliefs or values. Philosophical tensions contrast against structural tensions in that they have to do entirely with internal forces at work inside an individual, such as beliefs or expectations.

Teachers’ predetermined beliefs. A teacher’s predetermined beliefs can influence their instruction. Ross, Cornett, and McCutcheon (1992) discuss this topic when they say that “personal theories and beliefs serve as the basis for classroom practice and decision making” (p. 3). A teacher may be de-motivated by not valuing what they are to teach. “Teachers will not implement educational resources into their classes if they are not convinced of the value of the curriculum and do not understand how to use it” (Lawrenz, 1985, p.28). Mr. Wayne’s comments about how he is actively supplanting the BSAA curriculum with another (CASE) curriculum because he feels the BSAA curriculum is out of date and the proscribed labs are not professional enough (making use of “Dixie cups and q-tips”), is an example of this type of de-motivation. Mr. Wayne sees using Dixie-cups as having an unprofessional appearance, and therefore discounts the value of the curriculum. This discounting differs from Mr. Black who says using Dixie-cups is not an issue for him and embraces the simplicity and accessibility of the BSAA curriculum. His opinion is that science is messy (as is inquiry), and it comes with bad smells and all:

> Interviewer: Another teacher mentioned that the fermentation lab does not smell good and it is not good PR for students...
>
> Mr. Black: We have a... I don't worry too much about that. It gives us something to talk about... so what? But I understand. I'm not going to say they're wrong, but for me it's not a big deal. Science is messy, and I'll be honest with you, one of the things I really enjoy... when experiments do not turn out right, and helping kids think through why and what possibly could have gone wrong I love that, it's a great teaching tool, a great learning experience. And I don't get too worried about that.

Mr. Wayne professed a dislike of grading and the submitting of grades as a measure of evaluating students. His dislike of grading manifests in not using long-term projects in his instruction, despite his professed appreciation of the educational value of such projects. He also said that he discounts the value of standardized tests and dislikes educational jargon. This may be getting at something more, perhaps that he values authentic, tangible learning, such as he grew up with on the farm, and dislikes what he perceives as artificial, contrived measures such as standardized tests.

Teacher commitment to science integration. It may be that teachers, such as Mr. Green, experience tension because they believe that their primary responsibility is to teach agriculture, and therefore agriculture should come first. When Mr. Green started as an agriculture teacher at his school he was assigned to teach BSAA because he was the only qualified teacher; he did not have a choice. There may be a concern that once the decision is made to integrate science, the result may be a “deemphasizing of key components that make agriculture education programs unique and successful" (Myers & Thompson, 2009; Myers & Dyer, 2006) and a loss of the "unique identity and value if an emphasis on science-based instruction becomes the sole purpose" (Conroy, Dailey, & Shelley-Tolbert, 2000).

Teacher and student expectations. Teachers expressed a tension between their more fluid expectations for their students' learning and their students' desire to be presented with concrete expectations. This relates to the challenge teachers say they feel using inquiry-based learning vs. traditional teaching methods. Teachers say that their students are unfamiliar with inquiry-based approaches, and they "don't want to have to learn, they want to be told" (Mr. Black, Mr. Wayne). This tension stems from the teachers' expectations differing from the students' perceptions of their respective roles. It may be that the students feel the role of the teacher is to deliver content and the role of the student is to passively receive and memorize the content.

Coping with tensions. Teachers displayed strategies for coping with potential tensions. Mr. Wayne and Mr. Black each demonstrated a form of choosing to press forward with teaching even though they were experiencing a tension or dissonance. Mr. Wayne's choice to continue on in a dissection lab even though he was perhaps uncomfortable or unfamiliar teaching about comparative reproductive anatomy is an example of a teacher coping with a lack of knowledge or competence. Mr. Black twice demonstrated a decision to move on instead of becoming mired in a tension. He stated in his interview that he was unwilling to allow time constraints to force his pace through the curriculum, instead opting to teach fewer curriculum items more fully rather than teach all of them only cursorily. Mr. Black also chooses to press forward by using Dixie-cups and q-tips in science instruction (choosing to embrace science's sometimes inherent messiness and smelliness) instead of protesting a lack of sophisticated materials or demanding a different curriculum.

Research question #5: How do teachers blend science and agriculture in BSAA? On what do they base this decision?

Research question five sought to determine how teachers use and blend science and agriculture content in their classroom.

This is a spectrum that ebbs and flows as science and agriculture are blended in different ratios day-to-day, depending on the teacher's needs. For some, the purpose of blending science and agriculture together is to promote agricultural literacy in students. For others it is to teach mastery of the science content. For all, at different times, it is likely varying ratios of both.

This is where teacher's paradigms interact and engage with their practices/ methodologies. In this continuum of practice, Mr. Black seems to most often use agriculture to support science. In chapters IV and V, I presented many examples of teachers' various practices of teaching science and agriculture. Of these, I think that Mr. Black, in episode IV, serves as a good example. Here he uses the agriculture context of growing field crops (corn) to teach about plant physiology (photosynthesis). I think Mr. Black's goal was not to teach about corn, per se. His goal was to teach science. The agricultural medium of corn production served as a context in which to teach principles of science. This is a good example of agriculture being used in service to teaching science.

I think Mr. Black has an appreciation and respect for agriculture and knows it is an effective context in which his students learn. This respect and knowledge dovetail well as he blends agriculture in support of science. His ultimate loyalty is to the teaching of science and the distillation of science education, although he is not opposed or resistant of agriculture in any way. He could have just as easily taught his lesson from a framework decontextualized from agriculture. He believes that his students' science comprehension will benefit from the blending of agriculture and science.

Mr. Green said one of the advantages of BSAA is that he has a chance he would not normally see to expose students to agriculture, and he can use science to get them to walk through his door. By teaching a science class, these students not from traditional agriculture backgrounds get to learn about agriculture topics as Mr. Green blends science and agriculture, pulling his students in and intending that they will benefit from their experience. The basis for his decision would be maximizing the benefits to his students.

I believe Mrs. Flowers when she says she has a passionate and genuine love of agriculture, but I also believe her when she says her first commitment is to science. She said that she loves to get her kids excited about the context as they are exposed to agriculture in her class. Although she has passion for agriculture she still feels a primary responsibility to teach science. This drive to meet the science standards is a motivating factor for her. I think she may also want what is best for her students, which I think is making sure they are prepared in science. She made this clear in saying, "I would be scared if a BSAA teacher did not know the science."

Mr. Wayne's goals are to instill knowledge and use agriculture as a tool to equip his students for the future. He talks about instilling practical life skills and preparing his students to become educated consumers. He uses the confluence of science and agriculture to help his students to become informed, aware citizens. Indeed, this is reflective of his comments related to his dislike of standardized tests, instead desiring that they develop practical skills, "Can you do it or can't you?" he said was the measure of learning.

Conclusions

The overarching research question sought to describe and explore how a sample of BSAA teachers interpret and practice BSAA curriculum. Based on the findings from this study I propose the following: Regarding science and agriculture content, and the blending of, and dominance of one over the other, I think no teacher taught one to the exclusion of the other. While one was always in service to the other, neither was subservient to the other.

I saw that teachers will do what they want to do. They teach like they want to teach. This makes sense in the framework of the Sociocultural Model of Embedded Belief Systems and cognitive dissonance. These constructs both justify and explain why teachers do what they do with curriculum and inquiry. I think that teachers will find a way to use agriculture or science to justify their instruction because they are doing what they think is right based on what they perceive their students need.

Significance and Implications

It is important to think about how the results of this study are significant to the field of agriculture education. BSAA was created to address a need for science curriculum in agriculture. Inquiry-based instruction has been shown to be engaging and a good way to teach science content. Strong student engagement promotes learning. Student engagement may also lead to maintaining robust enrollment in agriculture programs, which results from the adoption and retention of students that otherwise may have found themselves in traditional science courses.

To promote effective use of inquiry-based instruction preservice educators may need to consider their respective pre-service training. If how you train teachers determines how they teach, then it may be that more training needs to happen in inquiry. Mr. Black was the only teacher to be trained in a system focused on inquiry-based instruction, and now he teaches that way. I cannot say there is causality there, but of the four teachers, the only teacher who received formal training in the use of inquiry-based instruction was the only one who consistently demonstrated the use of it in the classroom. If you want it, you must train for it. This may reflect a need for agriculture and science teacher educators to design and implement increased in-service professional development hours aimed at helping teachers to prepare for and conduct SI in their classrooms.

My findings also suggest that there are valid multiple methods to science instruction, and that no approach is invalid. They may not all be equally effective or intrinsically valid, but there are great ways of teaching content in every approach. Some of my participants used long-term and short-term projects, some used inquiry to varying degrees, but these agriculture teachers were all able to find ways to connect meaningfully with students somewhere along the line. Those connections are what makes the difference.

Recommendations for Future Research

This section presents suggestions for extending the findings of my study in future research. I engaged with my participants during segments of instruction of the BSAA curriculum. The implications for future quantitative research are large. One could measure inquiry's efficacy in agriculture, the efficacy of teaching agriculture and science in a blended format, agriculture teacher's attitudes toward inquiry, teacher's attitudes toward teaching agriculture and science in a blended format, etc.

Research could be done on how to measure the effectiveness of these methods. Much has been investigated, quantitatively, on how agriculture students perform versus their peers not enrolled in agriculture classes. Could studies of the teachers of these students be undertaken to see what methods they use in their instruction? These findings were for BSAA. Do these findings align with what might be found in the teaching of PSAA? Does it ring true there as well or is there something about biology that makes it more applied, more real, to students?

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APPENDIX A:

PARTICIPANTS' CURRICULUM AND LESSON PLANS

Mr. Black

Lesson A

Unit: Plant Science

Problem Area: Initiating Plant Growth

Lesson: Osmotic Turgescence: The Forces of Plant Growth

Student Learning Objectives. Instruction in this lesson should result in students achieving the following objectives:

1. Explain why the seed coat ruptures during germination.
2. Understand how soil condition affects seed germination and seedling establishment.
3. Explain how seedbed preparation affects germination.
4. Demonstrate an understanding of how germinating seeds work their way up through the soil.

Lesson B

Unit: Plant Science

Problem Area: Managing Plant Growth

Lesson: Separating Plant Pigments by Chromatography

Student Learning Objectives. Instruction in this lesson should result in students achieving the following objectives:

1. Explain different wavelengths of light.
2. Explain the role of light intensity of plant growth.
3. Identify the pigments commonly found in the leaves of plants.

Mr. Green

Lesson A

Unit: Plant Science

Problem Area: Managing Inputs for Plant Growth

Lesson: Principles of Heredity: Variation in Corn Student Learning Objectives. Instruction in this lesson should result in students achieving the following objectives:

1. Explain other types of relationships between alleles and how to determine the probable outcome of these relationships.
2. Explain how to determine the genotype of an unknown individual.
3. Demonstrate how the probability is determined for dihybrid crosses.
4. List four examples of mutations and explain how mutations can change the genetic make-up of an organism.
5. Explain how humans have manipulated the genetic make-up of organisms.

Lesson B

Unit: Food Science

Problem Area: Agricultural Processing Systems

Lesson: Making Ice Cream

Student Learning Objectives. Instruction in this lesson should result in students achieving the following objectives:

1. Describe the physical changes that occur in the ice cream mixture during freezing.
2. Explain the effects of sugar, salt, or similar molecules on the freezing of liquids.
3. Describe the ingredients and factors that give ice cream its characteristic smooth and creamy texture.

Mrs. Flowers

Lesson A

Unit: Scientific Research

Problem Area: Conducting Scientific Investigations in Agriculture

Lesson: BSAA: Designing and Conducting Agricultural Research

Student Learning Objectives. Instruction in this lesson should result in students achieving the following objectives:

1. Understand the importance of the scientific method.
2. Explain the steps in conducting research in agriculture.
3. Explain the importance of controlled research.

Lesson B

Unit: Plant Science

Problem Area: Agriculture and the Environment

Lesson: Sustainable Agricultural Practices Student

Learning Objectives. Instruction in this lesson should result in students achieving the following objectives:

1. Explain the importance of sustainable agriculture to agriculture and to society.
2. Explain each of the elements of sustainable agriculture.
3. Discuss the nitrogen cycle and its effect on plant nutrition.
4. Explain how technology is helping to improve sustainable agricultural practices.

Lesson C

Unit: Plant Science

Problem Area: Managing Inputs for Plant Growth

Lesson: Plant Tissue Testing

Student Learning Objectives. Instruction in this lesson should result in students achieving the following objectives:

1. Name the nutrients needed for plant growth.
2. Explain why nutrients are essential to plants.
3. Explain where and how plants can obtain nutrients.
4. Describe environmental conditions that influence nutrient deficiencies.
5. Explain where plants can obtain nutrients if inadequate amounts are present in the soil.
6. Discuss the nitrogen cycle and its effect on plant nutrition.

Mr. Wayne

Lesson A

Unit: Animal Science

Problem Area: Animal Reproduction

Lesson: Artificial Insemination

Student Learning Objectives. Instruction in this lesson should result in students achieving the following objectives:

1. Describe the importance of animal reproduction.
2. List the parts and explain the functions of female and male reproductive systems.
3. List and describe the phases of the estrous cycle.
4. Explain how artificial insemination is performed.
5. Explain the advantages and limitations of artificial insemination.
6. Explain new technologies that are being used in reproductive management of animals.

Lesson B

Unit: Animal Science

Problem Area: Animal Reproduction

Lesson: Sperm Motility

Student Learning Objectives. Instruction in this lesson should result in students achieving the following objectives:

1. Describe the importance of animal reproduction.
2. Explain how sperm are formed and how they differ from the female gamete.
3. Explain the three factors that are used to evaluate semen.