This is to certify that the

dissertation entitled

ELEMENTARY STUDENT AND PROSPECTIVE TEACHERS' AGRI-FOOD SYSTEM LITERACY: UNDERSTANDINGS OF AGRICULTURAL AND SCIENCE EDUCATION'S GOALS FOR LEARNING

presented by

Cary Jay Trexler

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Agricultural and Extension Education

Major professor

Date August 2, 1999

ELEMENTARY STUDENT AND PROSPECTIVE TEACHERS' AGRI-FOOD SYSTEM LITERACY: UNDERSTANDINGS OF AGRICULTURAL AND SCIENCE EDUCATION'S GOALS FOR LEARNING

By

Cary Jay Trexler

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

DOCTOR OF PHILOSOPHY

Department of Agricultural and Natural Resources
Education and Communications Systems

1999

ABSTRACT

ELEMENTARY STUDENT AND PROSPECTIVE TEACHERS' AGRI-FOOD SYSTEM LITERACY: UNDERSTANDINGS OF AGRICULTURAL AND SCIENCE EDUCATION'S GOALS FOR LEARNING

By

Cary Jay Trexler

Although rhetoric abounds in the agricultural education literature regarding the public's dearth of agri-food system literacy, problems arise when establishing educational interventions to help ameliorate illiteracy. Researchers do not fully know what individuals understand about the complex agri-food system. Hence, educational programs and curricula may focus on areas where students already possess well developed and scientifically accurate schemata, while ignoring other areas where incompatible or naive understandings persist. Democratic decisions about complex societal and environmental issues, such as trade-offs of our industrial agri-food system, require individuals to possess understandings of complex interrelationships. This exploratory qualitative study determines what two groups--elementary students and prospective elementary school teachers--understand about selected concepts foundational to agri-food system literacy.

To ground the study in current national education curricular standards, a synthesis of both agricultural and science education benchmarks was developed. This helped structure interviews with the study's informants: nine elementary students and nine prospective elementary teachers. Analysis of discourse was based upon a conceptual change methodology.

Findings showed that informant background and non-school experiences were linked to agri-food system literacy, while formal, in-school learning was not. For elementary students, high socio-economic status, gardening and not living in urban areas were correlates with literacy; the prospective teacher group exhibited similar trends.

Informants understood that food came from farms where plants and animals were raised. For the majority, however, farms were described as large gardens. Additionally, informants lacked a clear understanding of the roles soil and fertilizers play in crop production. Further, few spoke of weeds as competitors with crops for growth requirements. Informants understood that agricultural technologies saved time and reduced labor and were concerned with the immediate impact of agricultural pollution. They, however, did not link their food and fiber consumption with resources use or environmental impact. Additionally, half of the prospective teachers did not understand genetics well enough to discuss how humans engineer life.

Notable differences were found between teachers and students in 17% of the elementary benchmarks. Differences between the two groups were found in the elementary students' lack of ability to proffer cause-effect relationships, especially in regard to the use of agricultural technologies.

To Thomas who has helped me learn how to live life a little closer to one day at a time and to Erika, Jordan and Kieran for letting me be a part of their lives.

ACKNOWLEDGMENTS

I guess I should start at the beginning. I'm always asked how I got into agricultural education since I grew up in the suburbs of Los Angeles. I answer that I owe my love of earth and its creatures to my grandma and grandpa Trexler. They were the first to link me to the land, and I am indebted to them. In my formative years, my Uncle Denny--although I don't think he is aware of it--played an important role in getting me interested in science; I still remember my box of rock specimens. I thank him for helping to spark an interest that has remained with me to this day. From my parents, I gained high standards for quality and an ethic of doing things "right" the first time. Thanks for bringing me into this world, loving me, and for showing me the way.

As I reflect back, I also need to thank Jim Bailey for his help and encouragement when I was considering going into agricultural education as a career. My work in agri-food system literacy springs from Jim's insight as a Missouri farm boy living and teaching in Fullerton, California. Jim you are an excellent teacher and mentor--thanks for sending me down the path with the ideas that most urban people know little about the plants and animals that feed them, but that they are keenly interested to learn.

I've had the pleasure of meeting and befriending two extraordinary people while at Michigan State University--Tony and Jen--both of whom have been instrumental in keeping me physically and mentally fit. Thanks Jen for your encouragement and support. Tony, thanks for listening to me as I intellectualize the most trivial matters,

traveling with me to "educational" conferences, and for helping me see how others react to me.

Annette and Catherine, thank you for bringing such beautiful kids into my life. They are truly special to me and are a reflection of your love and respect for them as individuals. You are wonderful parents to my children.

Now onto the formal thanks. As a learner, I'd like to thank the two most influential teachers in my doctoral program-- Andy Anderson and Larry Busch. Andy thanks for your help with planning my dissertation and for providing deep and well reasoned feedback to my findings. Larry thanks for challenging me intellectually and for helping to ground me in theory I will use throughout my academic career. As to what I really wanted to learn while in graduate school--the ability to write clearly--I owe much to Kirk Heinze. Kirk thanks for "tinkering" with my writing. Also thanks for being a model dissertation advisor. I, throughout the writing process, felt supported and was given the latitude that I needed to complete the task.

There are two more friends that I must thank--Murari Suvedi and Hiro Hikawa. Murari, thanks for your stellar example as a scholar and researcher. I appreciate your constant encouragement and kind works. Hiro, thank you so much for your help with transcribing and with formatting. I would not have made the "drop dead" for the submission of this dissertation without your help. Good luck on your journey, Hiro.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

California Agricultural Literacy Framework- (CALF) (California Agricultural Literacy Taskforce, 1994)

American Association for the Advancements of Science (AAAS)

Benchmarks for Science Literacy- (Benchmarks) (AAAS, 1994)

I. INTRODUCTION

Overview

The past decade brought an increased awareness of and concern for environmental issues. Industrial agriculture production has come under increasing scrutiny by select agricultural producers and researchers (Schwarzweller and Lyons, 1995). Sustainable agricultural practices that focus on regenerating such natural resources as soil or water while maintaining or improving farm productivity are increasingly being adopted by farmers. Wilkins (1995) describes these production-based moves as being at the micro-level. Increasingly, there is an awareness that for sustainable practices to take hold at the macro-level, consumers--who drive production practices through their consumption of food and fiber products--must possess a basic understanding of their role in the human agri-food system (Berry, 1977; Wilkins, 1995). Consumers, however, are not conscious of how their eating habits affect the way the planet's natural resources are used (Berry, 1990). Gussow (1983) argues that:

> On a worldwide scale, the [agri-food] system is functioning so as to threaten our future food supply. But because the problem is difficult to see and because the connections between an imported winter fruit and soil erosion 2,000 miles away are difficult to make, consumers have not understood how to act in their own self-interest (p . 12).

Consumers of food and fiber products are unaware of the social, technological, and scientific trade-offs that the current system requires; the agri-food system is a "black box"

to most Americans. Black boxes store the technological underpinnings of systems and are concealed and unquestioned by most of society.

Latour (1987) asserts that black boxes emerge when networks of technology users accept the benefits of a technology without deference to their construction. These black boxes are no longer questioned, but accepted as part and parcel of life. Rouse (1987) cautions that society needs to critically question the use of scientific knowledge and technologies in order to determine what it values. To do this, people need to possess an understanding of scientific and technological principles to assess their implications for the environment and culture. Without this understanding, people are unlikely to move beyond consideration of their immediate self-interest (AAAS, 1989).

Acquiring such understanding is a cumulative process that begins when people are very young. If consumers are to move beyond their unconsciousness of the current system, US public schools must integrate human agri-food system concepts and examples into curricula. Education policy makers in both agricultural and science education shared this concern in the late 1980s. The National Research Council (1988), in its seminal report, Understanding Agriculture: New Directions for Education, coined the term "agriculture literacy" and suggested that the science of agriculture was too important to be taught to only those in vocational education. Concomitant to agricultural education's move toward redefining its audience, the American Association for the Advancement of Science (AAAS) called out for increased scientific literacy in the landmark publication: Science for All Americans. The association argued that "the boundaries between traditional subjects should be softened and more emphasis placed on

the connections among science, technology, and society" (AAAS, 1989, p.5). It also identified agriculture as one of the eight basic technology areas for study by our nation's students. As a result of these two policy documents, curricular goals for the agri-food system were written independently by agricultural and science educators.

Although these policy documents were developed with little or no communication between agricultural and science educators, some commonalties exist. As a component of previous scholarship, I analyzed the content of both agricultural and science education's curricular goals for agriculture to determine what each group believed important for people to understand about the agri-food system. Based upon this analysis, I developed a synthesis of the two disciplines' curricular goals as outlined in the documents above. In the synthesis, I included the language that would most likely be used by someone who understood the curricular objective outlined in the goal. In addition, I listed real-world contexts that might be used to illustrate understanding of the objective. Cognitive psychologists (Piaget, 1957; Resnick, 1987) argue that vocabulary and knowledge of specific contexts are essential in developing mental structures , called schemata (Anderson, Spiro, and Anderson, 1978), that link together requisite language and experiences into an understandable form. Michaels and O'Connor (1990) and Gee (1991) suggest that literacy is marked by one's ability to talk about a given topic using accepted language; verbal discourse, then, can be used as a measure of one's literacy.

Considering this notion of literacy, this study seeks to describe agri-food system literacy among two groups: elementary school students and prospective teachers who will teach elementary students. The synthesis of curricular goals for agri-food system

literacy described above will serve as ideal benchmarks to structure one-on-one interviews as well as to clarify the ideas and understandings of selected individuals from these two groups.

This study seeks to fill a gap that exists in both agricultural and science education. Although rhetoric abounds regarding the public's agri-food system literacy, problems arise in regard to teaching about the agri-food system. Researchers do not know what individuals understand about this complex system. Hence, educational programs and curricula may focus on areas where students already possess well developed and scientifically accurate schemata, while ignoring other areas where incompatible or naive understandings persist. Decisions about complex societal and environmental issues, such as trade-offs of our industrial agri-food system, require understandings of complex interrelationships. These understandings can lead to an appreciation of how one's actions contribute to how resources are used and of how humans restructure the world to meet their demands. Because it is designed by human hand, the organization of the agri-food system tells us much about what we value as a society.

A. Purpose of Study

The purpose of this exploratory qualitative study is to determine elementary student and prospective elementary school teachers' understandings of concepts foundational to an understanding of a sustainable agri-food system. The study has five objectives:

B. Objectives

1. To determine informants' backgrounds and experiences.
2. To describe how student understandings of the agri-food system compare to goal conceptions based upon a synthesis of Project 2061's Benchmarks for Science Literacy (1994) and the California Agricultural Literacy Framework (1994).
3. To describe how prospective elementary teacher understandings of the agri-food system compare to goal conceptions based upon a synthesis of Benchmarks and the CALF.
4. To ascertain if commonalties exist among informants with regard to their backgrounds and experiences and to their understandings of the agri-food system.
5. To ascertain if differences exist between the two groups relative to their understandings of the agri-food system.

C. Definition of Terms

agricultural literacy: "possessing knowledge and understanding of our food and fiber system. An individual possessing such knowledge would be able to synthesize, analyze, and communicate basic information about agriculture" (Frick, 1991).

agri-food system: a complex and interrelated assemblage of human-made networks that researches, produces, processes, distributes, markets, sells and reuses food and fiber products.

agri-food system literacy: an understanding of the natural and human-designed components of the system that produces food and an ability to hold discourse that explains and analyzes the system's effects on people and the environment.

benchmark: statement identifying expected or anticipated skill or understanding various developmental levels (Leising et al., 1998). Specifically in this study, benchmarks are taken from both the California Agriculture Literacy Framework (Leising and Zilbert, 1994) and Project 2061: Science for all Americans (1989).

experiences: experiences, both in-school and out-of-school (non-formal), contribute to the development of one's schema. In this paper, objectives one (1) and six (6) both seek to determine the experiences in which informants have engaged that may contribute to agri-food system literacy. Dewey (1916) suggests that experiences are more vital and meaningful to the individual than formal, in-school learning

literacy: discourse which comes from learning that allows one to reason and solve problems in social and cultural contexts (Gee, 1991; Michals and O'Connor, 1990).

schema: a sub-unit of mental structures forming a cognitive system developed through interaction with and assimilation of other pre-existing sub-structures. Schemata form through repetition and help people to make generalizations, because a variety of objects are capable of satisfying the repetitive process. They then help people to differentiate as a result of the variety. Piaget (1957) suggests that "... schemas, being instruments for adaptation to ever varying situations, are systems of relationships susceptible of progressive abstraction and generalization" (p. 99). In this study, schema are thought of as being loosely constructed and interchangeable slots or place holders that represent general knowledge structures.

science literacy: AAAS (1989) defines science literacy as relating to "education in science, mathematics, and technology - (that) should help students to develop understandings and habits of mind they need to become compassionate human beings ... and to participate thoughtfully with fellow citizens in building and protecting a society that is open, decent, and vital" (p. xiii).

sustainability: Redclift (1987) defines sustainability in an agricultural context as the "system's ability to maintain productivity in the face of a major disturbance, such as that caused by soil erosion, farmer indebtedness, an unanticipated drought or a new pest. The loss of sustainability is then expressed through declining productivity or sudden collapse in the system" (p. 18). It is important to note that this definition includes, but is not limited to: biologic, social, economic, and atmospheric parts of the system. The development of sustainable systems calls for a break from the linear model of growth and accumulation that serves to extract short term, unsustainable profits from the planet.

understanding: the faculty by which one understands, i.e., his/her intelligence, suggests full and clear knowledge, a mastery of, being conversant or familiar with a meaning or explanation. This includes being capable of judging with knowledge. This meaning suggests that which is understood is factual, scientific and truthful.

D. Limitations

This study will propose, not test, theory about what elementary students and their prospective teachers understand about the agri-food system. The goal, then, will be the development of concrete universals. Concrete universals (Erickson, 1986) are derived by studying a specific case in detail and then comparing it to others studied in equally great detail --a method appropriate to studying the schemata of individuals. Conclusions from this study are not meant to be abstract universals built by generalizing from a sample to a population, but rather are illustrative of what these informants understand in this specific context. Results are limited to this group and are not to be extrapolated to an another group.

Because I will employ cognitive anthropological techniques (Frake, 1980) to interpret the discourse of informants, the conclusions drawn will be constrained by informants' words and by my ability to draw patterns of meaning from them. Understanding of student thinking will be limited by my reliance on language as a primary source of data. Frake (1980) asserts that probing an informant's ideas through dialogue allows for the exploration and charting of idiosyncratic cognitive maps. It will be difficult keeping dialogue running, while, at the same time, pushing informants to the edges of their cognitive maps where their mental schemata (Anderson, Spiro, and Anderson, 1978) are hazy and their discourse limited. To chart informant maps, representation of an informant's ideas will be dependent upon the phrasing of interview questions and upon my interpretation and reporting of the content and organization of informants' words (Anderson and Demetrius, 1993). While analyzing informants' verbalizations, raw data will be changed into a synthesis of my thinking combined with evidence of the informant's thinking. Throughout my analysis I will strive to represent informants' ideas as accurately as possible by using their own words.

The ideas of both elementary students and prospective teachers will be compared to conceptions based primarily on educational standards outlined in Benchmarks and the CALF. To operationalize these standards, I will use a synthesis of these curricular guides which I previously developed. Therefore, this study is limited by four assumptions: 1) the Benchmarks are an accurate assessment of what people need to understand for science literacy, 2) the CALF accurately portrays what needs to be understood for agri-food system literacy, 3) the synthesis I developed accurately represents a merging of what both science and agricultural education deem essential for literacy and fills in any gaps found in the two perspectives, and 4) the benchmarks selected from the synthesis are those needed to develop a sequential understanding of agri-food system sustainability.

I would be remiss if I did not mention my bias toward the development of a more sustainable agri-food system. This bias, my own reflexivity, will most likely influence my interpretation of data and the conclusions and recommendations that I draw from the study. I agree with Saunders (1995); sustainability involves the belief that "present generation should leave to its children a legacy of natural and humanly-produced assets which is no more depleted than the one it received from its parents" (p. 56). I am deeply influenced by the arguments of academics and philosophers from the non-agricultural disciplines (Beck, 1992; Berry, 1977; Gussow, 1983; Goodman and Redclift, 1991; Thompson, 1995; Wilkins, 1995) who call attention to the agri-food system's corporate hegemony, its short and long-term social and environmental costs, and the consumer's role in the perpetuation of this system. I hope this research can contribute to developing an understanding of what people comprehend about the agri-food system. Without this knowledge, educators will be hard pressed to design effective programs to raise consumer consciousness relative to how their consumptive habits affect world-wide resource use and the ultimate sustainability of the planet.

II. REVIEW OF LITERATURE

Overview

This review of the literature serves to set the theoretical and conceptual framework for this study. It blurs the line between traditional academic disciplinary boundaries and calls upon the fields of the philosophy and sociology of science and technology, behavioral and institutional economics, and both agricultural and science education. The study builds upon a theoretical frame that uses the philosophy and sociology of science for the overarching goal of fostering democratic participation in the agri-food system. Behavioral economics provides a lens to examine choice behaviors and the ways in which individuals make decisions. Additionally, institutional economics lends a rationale for the banding together of individuals to act collectively. To operationalize the study, agricultural and science education provide the context for analysis through agri-food system curricular benchmarks. More broadly, educational theory (often employed in science education--but seldom in agricultural education) is reviewed to provide a conceptual framework for the study of agri-food system literacy.

A. Need for Agri-food System Literacy

The first section of this review of the literature briefly establishes the framework for this study. In the first portion, the need for societal understanding of the agri-food

system is present. Next, the risks associated with large and complex technological systems are examined in reference to society. Finally, unconsciousness of individuals in society about the agri-food system and their illiteracy are examined in terms of limitations on democratic participation.

1. Importance of a societal understanding the agri-food system.

> Many parts of our world are designed---shaped and controlled, largely through the use of technology---in light of what we take our interests to be. We have brought the earth to the point where our future well-being will depend heavily on how we develop and use and restrict technology. In turn, that will depend heavily on how well we understand the workings of technology and the social, cultural, economic, and ecological systems within which we live (AAAS, 1989, p. 89).

In modern society, consumers of food have, for the most part, abdicated the responsibility of supplying their sustenance to multi-national corporations. By doing so, consumers have also placed their trust and very lives in the hands of corporations that are driven more by profit motives than by concern for human health (Gussow, 1991). They become unquestioning and accept blindly a system they don't comprehend.

2. Risk in complex systems.

Risk is inherent in the pursuit of power and profit. Beck (1992) argues "the gain in power from techno-economic 'progress' is being increasingly overshadowed by the production of risks" (p. 13). For example, as chemical agriculture freed farmers from the fields with the use of fertilizers, insecticides and herbicides, risk of competition from pests for human food decreased. With this use of technology, however, risk shifted to the poisoning of the environment through the chemicals designed to reduce the risk of predation. As agriculture moves into the age of biotechnology, chemical corporations, such as Monsanto, buy seed companies and patent "life" such as, Round-up Ready™ soybeans. Risk shifts from poisoning of the earth to the creation of new life forms which have unknown long-term consequences.

Just as humans create new life forms through technology, they also transform and restructure rural landscapes around the world. Busch, Lacy, Burkhardt, Hemken, Moraga-Rojel, Koponen, & de Souza Silva (1995) in very simple, but powerful terms suggest that "the way we change nature reveals the kind of people we are" (p. 11). With these changes, the world and what technology can create become increasingly complex and risky. Beck (1992) argues that industrial society has been transformed into a society based on risk, or rather, the avoidance thereof. As society adopts increasingly complex technologies, whether they be aqueducts in California, Roundup Ready™ soybeans, automated beef de-boning machines, or systems for the shipment of winter grapes from Chile, risk is compounded and must be more vehemently controlled to avoid what

economists (Pigou, 1932; Eggertsson, 1990) call "externalities or spillovers." As externalities surface, winners and losers - in the social arena - are soon identified, and the un-sustainability of the current agri-food system is revealed.

3. Unconsciousness and its affects on democratic participation.

What is missing in the current agri-food system is a free flowing dialogue between those involved with research, production, processing, distribution, marketing, and preparation, and those who ultimately consume the products of the system. Scholars speculate that this is a result of an unconsciousness that has developed as citizens in industrialized countries have moved further from their connection to the land (Berry, 1977; Levenstein, 1988; Gussow, 1991; Thompson, 1995).

Berry (1990) effectively argues that food consumers have become passive, uncritical and dependent upon the industrialized food economy. He suggests that consumers suffer from "cultural amnesia" and know little of how food is produced, transported, prepared and assembled in today's modern society. For the past 10,000 years the overwhelming majority of people were directly involved in the production of their own food, people today have, either consciously or not, become disconnected from the food they eat and the fiber they use. With this disconnection comes what Berry terms as amnesia and a dependence on the industrial food complex and its farming methods that yield high volume and low price while precariously balancing risk to the environment and to human health and safety. Consumers--because they are not

educated about the origins of their food---are unaware of the risks and trade-offs inherent in modern agri-food system. Bird (1987) argues that:

> environmental problems represent situations in which some segment of society engages in practices that adversely affect other members of society and have the potential to injure the future quality and survivability of the planet. Moreover, those problems usually arise without a Democratic participation in choices that may drastically affect our lives (p. 264).

In Democracy and Education, Dewey (1916) states that democratic society relies upon the participation of its members to readjust institutions to meet the values of the majority. He suggests that education (and access to information) undergirds the democratic system by providing the individual with interest in social relations, control over his/her destiny, and an understanding of the need for social change without disorder. Unfortunately, there is a dearth of citizens capable of intelligently participating in democratic discourse that critically evaluates the agri-food system.

B. Society, Science and Technology

The second section of this literature review examines the interplay among society, and the science and technology it constructs. First, democracy is examined in terms of its evolving definition. Next, the consequences of society's unquestioning acceptance of science and technology is explored. After this exploration, unconsciousness and its

effects on democratic participation are examined in terms of who presently governs science and technology. This section closes by ascertaining the effects of public discourse on the application of science and the use of technology in society.

1. Evolving view of democracy.

To comprehend what democratic discourse and participation in the agri-food system might entail, it is necessary to first review the evolving definition of democracy. The application of power in society lays at the heart of democratic rule. In the case of externalities arising from the use of agricultural technologies, some person or person's rights are impinged upon. In the last quarter of the twentieth century a growing tension over the public's role in science and technology has emerged. This tension has been most apparent in the field of the biological sciences (Stemerding, 1995), because of an increased ability to use biotechnology to manipulate life and its potential for power and profit (Busch et al., 1991). Jennings (1986) describes the tension between the public and private succinctly:

> Private interests call for governance by accountable and responsive elites; fulfilling these interests primarily requires protection from the destructive or disruptive consequence of science. Democratic interests, on the other hand, call for active citizen participation; they require not so much protection from, as shared involvement in, science and technology. For democratic interests to be served, elite accountability and responsiveness are necessary but not sufficient; democratic interests require the further conditions of representative and perhaps participatory governance as well (p. 227).

In order to understand how democratic interests are championed in the realm of science and technology, it is important to review the evolving definition of this political ideal. Jennings (1986) describes three distinct streams of democratic thought that have emerged in contemporary political theory: liberal democracy, democratic revisionism and participatory democracy. Both revisionism and participatory forms evolved from the foundation of liberal democracy. As such, it is useful to review liberal democracy's major tenets. Liberal democratic theory holds that legitimate authority of the government rest in the hands of the governed. Individuals, then, have a right to engage in decision making that affects them and the society as a whole. When government acts, it acts at the will of the people, thereby achieving self-rule.

The self-rule can take two forms: direct rule or representative rule. Direct rule works extremely well when the number of people involved in government is small. Everyone can participate directly in the decision making. On the other hand, when the efficacy of rule becomes encumbered by the sheer number of citizens (as is the case in state and federal systems in the US), representative democracy is evoked. With representative democracy comes a loss of direct control and the possibility of subversion of the will of the governed, in other words, oligarchy. To guard against this danger, mechanisms are established to maintain the integrity of the representatives in light of what the represented value. This requires: 1) a free flow of information between the representative and the represented, 2) a citizen's capacity to understand and evaluate the work of the representative, and 3) elections to renew consent of the represented.

Along with the aforementioned procedural ideals comes the substantive ideal of democracy, the promotion of individual development by protecting individual rights, while at the same time promoting the public good. It is possible to have the procedures in place for a democracy, but not meet the substantive ideal. To foster this higher ideal, society creates institutions to "assure that democratic citizens have adequate intelligence, judgment, and quality of civic virtue, a moral commitment to justice and the good of community as a whole" (Jennings, 1986, p. 231). Most of these institutions serve to help society to structure its members to obtain an ideal that is difficult to obtain. For example, schools are institutions where shared beliefs, morals, ideals and knowledge are inculcated in society's young.

Some theorists argue that it is nearly impossible to develop citizens of such high moral standards and intellectual development, and strong commitment to others. These revisionists believe democracy has evolved into a different form--this new form is known as democratic revisionism. This refined notion of democracy places greater emphasis on the role of professional experts and elites who govern in a highly complex, technocratic system. Revisionist believe that citizens have not the ability to make the right decisions to maintain and promote a democracy that fulfills the procedural and substantive ideals of liberal democratic theory. Jennings (1986) argues that:

> revisionists believe that citizens "live in a condition of general political apathy punctuated only by discrete interests, preferences, and fears" and that "democratic institutions . . . are a means to achieve the values of political order and liberty by protecting against the permanent monopolization of political power by any single elite, and by protecting citizens against the unjust or exploitative exercise of private power in society (p. 234).

On the opposite end of the democratic theoretical continuum lays participatory democracy. Theorists advocating it believe that the ideals of liberal democracy have not been attained. They argue that an eroding of individual political action and an over dependence on elites has led to a decease in the efficacy of liberal democracies. The answer for them, then, is to empower citizens by promoting involvement in decisions that directly effect the lives of the governed. By doing so, democratic participation itself enhances the political reasonableness, judgment, and civic sensibilities of the participants. Jennings (1986) suggests that "achieving government for the people requires the creation of a certain kind of 'people,' a political community composed of genuine citizens" (p. 234).

2. Consequences of blind acceptance of science and technology.

The nurturance of political community necessitates some shared values. Sociologists argue that the society in which one lives influences the beliefs, values and behaviors of the individual. With respect to the use of science and technology in the modern epoch, society has increasing sought to rationalize all aspects of the world (Weber, 1958; Feyerabend, 1978). In capitalistic societies, Feenburg (1995) suggests that technological rationalization is defined as a means to the goals of profit and power. Feenburg persuasively argues that common people have a decreasing role in shaping technology in society. Masters of the technology system (corporate and military leaders and professional associations) wield enormous power in the public sphere as they pursue profit and power. As citizens accept the "legitimacy" of technology, it leads to hegemony. Feenburg (1995) defines hegemony as a "form [of] domination so deeply rooted in social life that it seems natural to those it dominates" (p. 12). This hegemony, like Weber's Protestant Ethic, arises within a time-specific context. Technologies, too, arise during specific time horizons. A horizon refers to culturally general assumptions that form the unquestioned background to every aspect of life. Feenburg (1995) argues that "rationalization ... and technological design is the key to its effectiveness as the basis of modern hegemonies. Technological development is constrained by cultural norms originating in economics, ideology, religion, and tradition" (p. 11).

3. Unconsciousness and its effects on democratic participation.

The hegemony described by Feenburg is the result of acceptance exacerbated by an unconscious citizenry. Science and technology have become so specialized and complex that many ordinary citizens cannot comprehend it without a knowledge of how it works. Without that knowledge and understanding, it is exceedingly difficult to govern the use of science and technology democratically. Winner (1995) suggested that technology is isolated from public life and citizens are encouraged to shape technology only in the market or other highly privatized settings. As a result, "there is no moral community or public space in which technological issues are topics for deliberation, debate, and shared action" (Winner 1995, p. 73).

Just as theorists argue that democracy has changed, so do those studying the origin of scientific and technological decisions. Stemerding (1995) argues that democracy no longer exists for science and technology:

> the image of a democratic society that is properly exercising choices on the application of scientific knowledge, should be replaced by another image: a society in which the introduction of new technical options is predetermined by existing networks and regimens (p. 150).

Green (199) echoes the notion of decisions made by networks of actors:

> public decisions making does not take place centrally in the government, but in networks of social actors extending widely into the society, networks which have emerged and developed especially in areas of high technology (p. 152).

If networks of elite actors in government, science and industry control the decisions made in science and industry, how can the hegemony described by Feenburg be challenged?

Typically change in the current system emerges as technological control systems fail. The externalities of science and technology spill over to endanger human health and safety, and environmental viability. As a result, democratic participation and public discourse are brought to the fore.

4. Public discourse: A modifier of science and technology in society.

Public debate often arises out of concern for that over which society has little or limited knowledge. Typically these are expressed as social issues in the realm of unknown risks to health, safety and the environment. Beck (1992) argues that modernization and its underlying rationality lead to the growth of mechanisms to control and contain the possible damages caused by the use of technologies themselves. Hennen (1995) suggests that:

> the shape of the future is increasingly dependent on decisions which are made now, without being able to grasp their consequences in their entirety. These "unknowns" leave many with concerns for the future and feeling of distrust in technologies and their promise of a better life (p. 93).

This is compounded by the fact that as technological systems become more complex, they also become more difficult for lay people to understand. As technological systems become increasingly rationalized, they become "anonymous," (Hennen, 1992) or "black boxed" (Latour, 1987). People's decisions and actions are removed from the temporal and spatial limits to spheres of action. In other words, they can no longer understand or see the technology in their lives; they simply use it unquestioningly. Further, people no longer have direct control, their actions are mediated through socially constructed interactions. Often these complex interactions are mediated through expert systems because of their complexity. Consumers of the fruits of these expert systems abdicate

much control over their lives to these very systems. As the everyday use of these systems becomes commonplace, Hennen (1995) suggests that:

> security of action no longer lies within the competence of the individual, but has to be guaranteed socially (including scientifically and technologically), making it a political element. With growing everyday practical dependence on expert systems (or in the broader sense on technology provided by expert knowledge), trust in "expert systems" becomes a central resource of social integration. The trust in anonymous "expert systems" needed in modern society to ensure security of action is inevitably precarious (p. 94).

If the expert systems perform with few mishaps, people develop confidence in the technology. If, however, the system itself is confronted with problems of its own creation, and has no means of ameliorating the problem, trust in the expert system breaks down (e.g., insecticide residues in food, bacterial contamination in meat, environmental degradation in agricultural production). In other words, as science and technology become more complex, they are matched by the growth in complexity of the possible side effects of scientific or technological action. Hennen (1995) suggest that:

> to the extent that expert systems overreach themselves in handling the consequences of their creations, as a result of their increasing complexity (knowledge proves to be uncertain/provisional, consequences as unperfected and socially produced major risks which cannot be secured against), lay people are forced to expand their outlook (p. 95).

Often little debate occurs over the adoption of a new technology in the public realm. Debate may occur among the "networks of users and experts" but seldom trickles down

to the masses. If scientific discovery or technological innovation does surface in the public sphere, it is most often a response to the cognitive and pragmatic unclarities or uncertainties typical of modern societies.

C. Choice and Education from an Economic Perspective

The third section of this literature review examines how individuals go about making choice decisions. This review provides insight into how educational interventions might be designed to help individuals weigh risk and make well-reasoned decisions. First, decision making strategies are examined at the personal level. Next, the notion of a rational human is challenged by research from behavioral economics. This is followed by a look at interdependence of people and how they organize themselves to make decisions valued by groups. Past public policy issues of the agri-food system are reviewed and emerging trends are explored. The section concludes with implications of behavioral economics for establishing educational initiatives that help people with evaluating choice decisions.

1. Choice and education.

Society, as users of science, is dependent upon and accepting of technologies. It, however, is oftentimes unquestioning of the long term effects of these innovations in terms of human health and safety and impact on the environment. To achieve the

substantive ideal of democratic theory, it is incumbent upon society to help its members learn to make informed choices, choices which, in the realm of science and technology, impact the individual and society at their cores.

Education, helping people gain the ability to make informed choices, is difficult. Humans are much less rational than most classical economists would lead us to believe (Sen, 1982; Simon, 1957). Behavioral scientists and those concerned with cognition and choice provide insight into how people go about making decisions on a practical level. These insights have direct bearing on goals for educational programming.

There are four powerful ideas that, if understood by those seeking to understand human behavior, can help them in their work: 1) choice behaviors are not always based on a rational choice model (Gazzaniga, 1985; Sen, 1982; and Arrow, 1987) ; 2) people often do not look to the long term when making decisions (Frank, 1987); 3) people use heuristics when making choices (Margolis, 1987); and 4) choice decisions (behaviors) depend on knowledge structures held in the long term memories of the brain's cognitive inventory (Piaget, 1950; Margolis, 1987). The following review of literature will shed more light on these ideas and speak to their implications for helping people become conscious of how their actions can influence the environment.

The difficulties in helping people comprehend and then take action upon long term consequences of their short-term behaviors are troublesome. Christoff (1996) points out in Ecological Citizens and Democracy that:

> environmental degradation - such as pollution of the groundwater aquifer - may take decades to reveal itself and may also persist for hundreds or thousands of years, affecting many generations of humans and other species and altering the time-frame over which consequences of decisions must be assessed. We decide not only for ourselves and our children, but often for our children's children. Yet information required for ecologically sustainable decisions about production, consumption and environmental protection increase in complexity as the intensity or scale of human intervention increases (p. 158).

As eloquently stated above, as systems become more complex, they become more difficult to understand. Douherty and de Geus (1996) echo this notion, while also relating it to democratic participation, "the impact of contemporary ecological degradation may be most keenly felt by those living in the future at a time well beyond the point when the degradation was caused. This suggests the need to think about how obligations to future generations might be related to democracy" (p. 7). Long term consequences, as determined by societal action or inaction, are obscured by the short term gains that modern technology so efficiently produces. As society makes a decision to pursue a certain course, one might compare it to a cigarette smoker, who, if he takes the time to reflect upon his actions, rationally understands the long term consequences of his actions, but sees the time horizon as being too far in the future to worry about the possible risk of cancer.

Kunreutner and Slovic (1978) argue that inability to understand and weigh risk is based on several factors. First, borrowing from Simon (1959) and Frank (1987), they argue that people possess a limited capacity to handle the multitude of events happening around them on a daily basis. Kunreutner and Slovic discuss "bounded rationality" or

"limited attentional capacity" and its effects on decisions. People, in order to cope with an increasingly high volume of information, tend to bind what they allow into their thinking mind. Kunreutner and Slovic (1978) argue that even intelligent citizens cut off much information that enters their world so that they can function in the complexity around them.

A second idea having bearing on how people make decisions is the notion of an individual's reaction to risk. Kunreutner and Slovic (1978) suggest that "people ... are not inclined to worry about low-probability hazards" (p. 67). This has a direct effect on the ability to bring the "big" issues of environmental degradation to the fore, issues that will have low probability of coming to a head in a short time horizon, but that will in the long run have a high probability of coming to fruition. Considering this, it would be very difficult to help people understand that their decision to purchase large, unblemished heads of lettuce during January in Michigan, for example, may contribute to fertilizer and pesticide contamination of the groundwater in California's Salinas valley and to the decline in fossil fuel reserves. From this insight, it becomes evident that consumers are more concerned about risk when there is a high probability of a low loss affecting them directly. They are less willing to spend money, or modify their behavior for that matter, on low probability and high loss risks such as groundwater degradation. This has direct implications on how educational programs directed at helping people learn how to analyze their choice decisions should be designed.

Kunreuther and Slovic (1978) suggest that people have difficulty conceptualizing the probability of risk over time. People are better able to deal with and sort out issues and events that have occurred in the short term. They have a limited capacity to make utility maximizing choices if they are difficult to understand (Kahneman and Tversky cited in Frank, 1987). To help them understand the long term consequences of groundwater contamination, educators can look to increasing the perceived probability of disaster by lengthening an individual's conception of a time horizon for decisions. For example, educational programs can focus on the probability in the long term (25 years down the road of a 100 year catastrophe verses a one-year time span). Ultimately, Kunreuther and Slovic (1978) argue "policymakers ...[and educators] must find ways to communicate the risks and arouse concerns for the hazards" (p. 67) among people so they are able to make informed choices.

The positive effects of public education can be measured by an understanding of risk and the ability to make informed choices. Frank (1987) suggests that "people do often want to alter...behaviors once their consequences become clear to them" (p. 227). Therefore, people need help in awakening into consciousness. Relative to consciousness of risk, then, educators can strengthen interventions by incorporating the ideas and theories relative to limits in cognition and how these influence consumer behavior.

2. Rational or irrational choice?

Frank (1987) argues that behavior often contradicts the rational choice model and is based on an asymmetrical value function which frames consequences in numerous ways and influences decisions. In other words, people don't always think the same about all

things --they place more value on the consequences of certain decisions when compared to others (they are not always utility maximizing). When making decisions, people place more weight on losses than gains (intuitively it would seem the opposite). They value losses more greatly than they do gains. This is helpful to consider when designing an education program highlighting the risks inherent in the production of lettuce using modern production practices. If one really wants to "sell" this risk, it seems that the possible negative consequences of this practice should be highlighted. If people are truly satisfiers and not maximizers, as Simon (1957) argues, they would be more pursued by short term, immediate threats to their health, rather than long term, sustained morbidity to a distant ecosystem and its people.

Another idea related to choice is that people hold common decision heuristics or "rules of thumb" (Frank, 1987). A heuristic is typically thought of as a way to come to understanding. In this case, people weigh decisions on the perceived frequency of events occurring. To make these decisions, they call upon the recollection of relevant examples and compare these to preexisting mental schemata (Piaget, 1957) or patterns (Margolis, 1987) or knowledge structures (Kunreuther and Slovic, 1978). To save time and energy related to information processing, people tend to fit new information into preexisting mental frameworks. The choices people make, then, are dependent upon the representativeness of a given person, idea, or event relative to similarities with which they are already accustomed. Again, this idea points out that a person's schema is called upon to help make choices. Choice behaviors are also affected by the anchors people choose and the adjustments they make to easily knowable (simplistic anchors) conceptions

(Frank, 1987). As they evaluate consequences of possible outcomes, people often underestimate the ramifications of decisions by adjusting them to a simplistic, and inaccurate, anchor. Rather than looking deeply and critically at choices to be made, people select frames of reference (anchors) that quickly and simplisticly help them make sense of their decisions. Often, if the anchors are not well suited to the decision to be made, the choice made does not result in the anticipated outcome.

In sum, choices are based upon an individual's mental maps or schemata. These idiosyncratic maps evolve as a result of social interaction and experience (Arrow, 1987). Educators wanting to help people make conscious decisions can benefit from designing interventions that reach people on a visceral, affective level, and once this connection is made, provide information for assimilation into the more logical portions of the brain. By constructing messages that conform to the way people make decisions, educators can capitalize on theoretical constructs that maximize the efficacy of educational interventions.

3. Interdependence and power.

People are interdependent; their welfare is affected by the acts of others (Schmid, 1998). People perceive people, places, ideas, and things differently and hold different values. When values differ measurably, conflict often arises. Even though conflict is probable to carry out interdependent functions, people work together to maximize what each party seeks, in other words to achieve a desired joint impact.

Institutions are formed by people to achieve joint action, the realization and acquisitions of tastes and preferences. These tastes and preferences are influenced by what a given group of people value within a context-specific period of time (as preferences are a moving target that change based upon a given social milieu). In turn, these values influence a choice process determining and limiting specific opportunity sets within a finite set of alternative possibilities. When choices are made, power is exercised (Samuels, Medema, and Schmid, 1997). Power, as it is acquired and exercised, tells society "whose voice prevails and whose choice matters" (Schmid, 1987, p. 228).

Power, as a function of whose rights count and whose choices prevail, is typically socially constructed in the marketplace and through politics. Ultimately, rights, or the lack thereof, are defined in the legal system, what Warren (1989) terms the legal-economic-nexus. At this nexus, the legal and economic systems intersect to determine whose preferences institutions value as they valorize and register interests and opportunity costs (Samuels, Medema and Schmid, 1997). Those who prevail in getting their rights carved in institutional stone are protected by a socially constructed wall; those who don't may suffer costs as the wall crumbles under the forces of those it protects. Most often, this protection serves to maintain the hegemony perpetuated by those whose interests and preferences are embodied within governmental laws and institutions. In sum, institutions serve to structure, constrain, and liberate individual behavior. They set paths for the distributions of income, wealth, costs and benefits materializing from opportunity sets (Schmid, 1998).

Public policy decisions are the result of shared images for the future. These images are oftentimes conjured up in an individual's consciousness through personal experience, messages delivered through the modern media, educational programming, popular culture, etc. For an image to be shared, it must be brought into the collective conscious of society; it requires a critical mass (Schmid, 1998). Once an image is brought into the consciousness of a group, it enters into the realm of the public. Groups of people sharing the same, similar, or complementary images may choose to band together collectively to achieve a desired result. The primary reason for this coupling is that individuals can't get their needs met by other means.

4. Public policy and the agri-food system.

Relative to the agri-food system, public policies have historically dealt with uncertainty relative to insuring a stable, high quality and inexpensive food supply. Farmers are protected through price supports that limit their exposure to risk from abrupt changes in market conditions and competition from foreign competitors (AAAS, 1993). Recently, consumers of food products banded together to push through legislation that shifted the burden of acquiring information about food products. Food producers are now required to meet a uniform labeling code that provides information on the nutritional value of food, its ingredients, etc. This information was simply too costly for individual consumers to ferret out on an individual level. Through joint action, however, the cost of gathering this information shifted from consumers to the producers of food. This change

in public policy was fought out at the legal economic nexus (Samuels, 1989). In the case of food labeling, the status quo and the hegemony of the US food conglomerates did not prevail--a testament to joint action within the agri-food system. In the future, if current events in Europe are any indication (and social trends oftentimes happen in Europe before springing up in the US), people in the US will become increasingly concerned about the health and safety of foods. They will be more concerned with its wholesomeness and the effect biotechnology plays in bringing food to their plate.

Many food products purchased by consumers at grocery stores have no information available relative to their origins or method of production. This is increasingly a concern for a growing number of consumers, because they are conscious of how selected production techniques negatively affect the environment and, as a result, seek to purchase products that are produced in ways that are less harmful to the earth. A problem, however, arises when consumers seek to make informed purchasing decisions; information costs are too high for most to pay. Some consumers are willing to pay this higher price by ferreting out information through research, contacting local producers at farmers markets, or buying seasonal food from roadside stands. Most, however, don't have the time, skill or tenacity.

Many agricultural producers and firms prefer the status quo of limited disclosure of information about the origin of food products. Schmid (1998) suggests that "existence of transaction costs protects the utility of those interested in the status quo . . ." (p. 2). In the agri-food system, transaction costs, in the form of information, arise for consumers, for example, when they desire knowledge about production techniques for agricultural products or about the genetic structure of the plants and animals themselves (e.g., Roundup Ready™ soybeans and livestock with manipulated genetics).

As the agri-food system becomes increasingly dependent upon science and technology, the system becomes more complex and agricultural products become harder to trace to their origin and the opportunity for some part of the system malfunctioning increases. Consumers lose control of that which they place into their bodies.

In the US, Schmid (1987) suggests that "one way for consumers to save information costs is to have the right to expect that only goods that meet certain standards may be sold" (p. 4). Will consumers in the future have a right to know if their food comes from transgenic sources? It will be interesting to see if the same scenario, as has occurred in Europe recently, plays itself out in the US markets in the future.

The quest for knowledge on the part of some consumers poses problems for the agri-food conglomerates. As Schmid (1998) points out, if consumers gain access to "new knowledge" of products, demand may change. The current hegemony--the status quo--is preferable to those with power. If, for example, people in the US became more conscious of the way in which poultry or swine are raised (in intense confinement on an astronomical scale and in an unsustainable fashion), some might choose to disseminate this knowledge to others. As a result of these information expenditures, it is conceivable that large, vertically integrated firms involved in production of livestock through the marketing of pre-packaged consumers goods, might suffer. Demand for these products could decline domestically. Therefore, many agri-food system stakeholders may believe that education about the way plants and animals are raised in "modern" farms could be detrimental for their market share.

5. Implications of behavioral economics and choice for education.

Although most classically trained economists believe the rational choice model describes how people make decisions, behavioral economists call this assertion into question. People oftentimes behave in ways that are not in accord with the values they hold and do so with incomplete information. They simply act, and then sometimes, try to rationalize their actions ex post facto. At other times, they follow decision heuristics that help them make their way through the astronomical number of choices required on a daily basis. These decision heuristics are often grounded on false assumptions about the way the world actually works and are used to satisfy wants and desires, rather than to maximize them. By understanding how people regularly behave, those seeking to educate about a given issue can leverage resources to capitalize upon how people go about making choices. Educational interventions can be designed to meet optimal benefits. Realizing that people have a definite modularity to the way they think helps to explain why people behave in ways that are contrary to the values they profess. Considering this, it is no wonder that they often seek to establish institutions to help them meet their higher aspirations. It is an intriguing concept that in order to establish such structures, they need to find others who share the same or similar concerns for the future. The images must be conjured up in the minds of many for joint action--this is where the need for an educated citizenry--with the ability to make informed and well reasoned choices--becomes most needed.

D. Education and Learning Theory

The final section of the literature review focuses on agricultural and science education and learning theory. First agricultural and science education curriculum documents for agriculture are discussed. Then a focused review of agriculture literacy's evolving definition is reviewed. Next, the science education curricular benchmarks are reviewed and critiqued for agriculture. Following this critique are lessons from science education that have implications for the study of agriculture. The final part of this section reviews conceptual change and sociocultural learning theory in the broadest sense and then narrows to an examination of two science studies that are templates for this investigation.

1. Promoting democratic choice through agricultural and science education.

Agricultural educators are increasingly concerned that the US citizenry is not equipped to make intelligent decisions relative to trade-offs inherent in the agri-food system. During the 1990s, many argued that more people needed to be educated about agriculture and the human food system. Agricultural educators advocated the integration of agricultural concepts into the school science curriculum (Trexler and Miller, 1992;

Leising and Zilbert, 1994; Birkenholz et al., 1994; Frick, Birkenholz, and Machtmes, 1995.)

Concomitant to agricultural education's move toward redefining its audience, the American Association for the Advancement of Science (AAAS) in Project 2061: Science for All Americans (1989) stressed the need for increased scientific literacy. The Association urged that learning of science and technology be connected to the lives of people, so that they are equipped to make sound and reasonable judgments about their use. Specifically the Association laid out curricular goals for the agri-food system in Project 2061: Benchmarks for Science Literacy (Benchmarks) (1993). This section of the literature review explores the salient findings in both agricultural and science education and underscores how research in science education can serve as a basis for determining the level of agri-food system literacy among children and adults.

2. Agricultural education.

a. Pursuit of agriculture literacy

The National Research Council, in its landmark study Understanding Agriculture: New Direction for Education (1988), coined the term "agriculture literacy" and suggested that a minimum level of understanding about agriculture was needed by US citizens. The study spurred many academics to re-think the role agricultural education played in the larger educational system. With this self-assessment came battles of rhetoric in the agricultural education press. These battles were fought to win the crown of defining the new goal for agricultural educators--agriculture literacy. Frick and Spotanski (1990) suggested that agricultural literacy encompassed an understanding of the processes and methods used by agriculture, basic agricultural terms, and the impact of agriculture on society. Law (1990) posited that:

> agricultural literacy may be defined as the development of the individual in the principles and concepts underlying modern agricultural technology. It applies to producing, processing, distributing, marketing, and consuming the products of the food and fiber system. It also includes an awareness of the impact agriculture has on the environment, on society, and on everyday living of the individual. (p. 5).

In a well reasoned position paper, Russell, McCracken, and Miller (1990) asserted agricultural literacy would entail "historical understanding, social significance, economic contributions, scientific understanding, and awareness and understanding of agricultural careers" (p. 13).

After this initial war of words, Frick et al's. (1991) conducted a Delphi study of US agricultural leaders to define and determine the components of literacy in agriculture. Agriculture literacy was defined as "possessing knowledge and understanding of our food and fiber system. An individual possessing such knowledge would be able to synthesize, analyze, and communicate basic information about agriculture" (p. 10). The study suggested seven components of literacy: a) Societal and Global Significance of Agriculture, b) Public Policy in Agriculture, c) Agriculture's Relationship with the

Environment and Natural Resources, d) Plant Science, e) Animal Science, f) Processing of Agricultural Products, and g) Marketing and Distribution of Agricultural Products.

In a study building upon Frick et al. (1991) Delphi work, Leising and Zilbert (1994) described the development of the "The California Agriculture Literacy Framework" (California Agricultural Literacy Taskforce, 1993). Thirty-nine people from agricultural constituent groups were involved in an iterative process using the nominal group technique to surface and refine content for the framework. Six themes were identified to serve as a foundation: 1) Food and Fiber Systems: Understanding Agriculture, 2) Historical, Cultural and Geographic Significance, 3) Science: Agricultural-environmental Interdependence, 4) Business and Economics, 5) Food, Nutrition and Health, and 6) Career Pathways in Agriculture. Each of these themes were fleshed-out with curricular goals and objectives and assigned grade-level content. The California Agricultural Literacy Framework (CALF) is a reasonably well-designed curricular guide and was adopted in Pennsylvania and Oklahoma for their agriculture literacy efforts.

To strengthen the CALF, directors of the project should have included diverse opinions and ideas about how the agri-food system could be structured more sustainably. The CALF document would be more balanced if alternative agriculture groups were more involved, and if science and environmental education curricular goals were more fully consulted in the development process. Only three of the fifty-five references cited in the framework were from science or environmental education sources.

b. Agri-food system literacy: Redefining the literacy goal

Although the works of Frick et al. and Leising and Zilbert are laudable and serve to promote education about agriculture, their work is also somewhat limited. In the case of Frick et al. (1991, 1995) and the other researchers following his work (Birkenholz et al., 1994; Flood and Elliot, 1993; Terry et al., 1992), methods to determine literacy are severely limited. These studies proceed as if abundant knowledge and positive perceptions gleaned through survey research equate to literacy. However, Frick and Wilson (1996) suggested that agricultural literacy involves, not simply a cache of facts, but "a basic understanding of agriculture, the agricultural industry, and its importance to our country and citizens" (p. 59). To "understand" is a personal affair, one entailing a struggle to grasp meaning (Dewey, 1933), and one not readily measured through impersonal survey methods. Evaluating idiosyncratic understanding requires interpreting a person's ideas about the relationships between things, not simply facts known. If literacy is to be evaluated and understood by researchers, the discourse of individuals must be made evident (Anderson, 1994; Rosebury, Warren, and Conant, 1992). Hence, survey findings of many agricultural education researchers do not lend themselves to an accurate picture of what people understand about the agri-food system. This is particularly troubling when considering that: 1) survey research methodologies dominate the agricultural education field, and 2) findings from these surveys guide curriculum development about the agri-food system.

To help rectify this deficiency, I developed a synthesis of curricular goals for my science education comprehensive examination. I included the language and real-world contexts that would most likely be used in discourse about the agri-food system. In addition, I modified the CALF to include greater emphasis on sustainability of the food system and on disposing of excess food and other agricultural waste products. This synthesis became the basis for this study and selected benchmarks are found in Table 1.

Gussow (1991) argues that "the task of those of us who wish to save real food is to reach the public through their existing environmental concerns. By doing so, educated consumers can make food choices that not only enhance their own health but also contribute to the protection of our natural resources" (p. 113). I hold a similar view and, hinge my definition of literacy upon the concept of sustainability of the agri-food system. Hence, my definition builds upon the "agriculture literacy" definition by including greater emphasis on environmental concerns and including sustainability. Exempt from the "agriculture literacy" definition, but included in the Table 1, is the notion that consumers demand the intentional transformation of the material world, for example, through their desire for winter vegetables, their demand for tropical fruits, their preference for pre-prepared foods, or their desire for a consistently tender steak.

Agri-food system literacy requires knowledge of the natural and human designed parts of the system as well as an understanding of the relationships each part has to the others. For example, consumer demand for prepared salads requires transformation of the material world and mandates the use of new technologies. As such, farmers might be required to plant new varieties of lettuce that, because of their genetics, has a longer shelf life when shred than traditional varieties, while packers must implement new systems for handling the "value added" product. The adoption of these technologies results in: a) a consumer's loss of control over food preparation, b) a greater centralization of the food system profits, and c) the loss of family-centered meals. On the other hand, the example of prepared salads also allows for: a) less spoilage of lettuce, b) more jobs in the food sector, c) greater freedom from meal preparation and d) greater profit for the packer/shipper. Obviously there are positive and negative trade-offs in paying for the convenience of pre-prepared salads. A person who is agri-food system literate would be able to have discourse with another person about a food product, such as the salad example, and explain some of the trade-offs inherent in the network of transactions that take place from production to consumption.

In 1999, the National Council for Agricultural Education released "A New Era for Agricultural Education: Reinventing Agricultural Education for the Year 2020" a W. K. Kellogg Foundation funded study that set forth an expanded vision for agricultural education. The vision includes as its third goal that: "All students are conversationally literate in agriculture, food, fiber and natural resource systems" (p. 4). This defining of literacy through discourse is a progressive and insightful step forward by leaders in agricultural education. They, however, have not defined the language or structure of this discourse. They might be well advised to look to those from other disciplines who have studied how literacy--as defined through oral and written discourse--can be promoted.

Linguists have joined science educators in trying to figure out how to foster science literacy through oral discourse. Gee (1991) suggests that literacy involves discourse which comes from learning. Michaels and O'Connor (1990) concur arguing that literacy is defined as the ability to reason and solve problems in social and cultural contexts.

In agriculture education it seems reasonable that communicative literacy would involve discourse that would describe, explain, analyze and criticize the system. Certainly, my definition of agri-food system literacy and expectation for discourse would not be the same for elementary school children as it would be for elementary teachers. Table 1. presents a partial synthesis of the Benchmarks (1993), the best thinking of agricultural educators Frick et al (1991) and Leising and Zilbert (1994), and my own concern for the need to understand sustainability issues inherent in the agri-food system.

3. Science education.

a. Science education's benchmarks for the agri-food system

Of the two science education policy guidelines published in the first years of this decade, Benchmarks (1993) and the National Science Standards (1995), only Benchmarks explicitly suggests that agri-food system content be taught in the nation's schools. Benchmarks suggests students learn about the interface among science, technology and society in relation to a world that is increasingly designed and controlled by humankind. To do this, AAAS argues that agri-food system examples and concepts be integrated into science, mathematics, social studies, and history curricula.

Benchmarks further suggests that in the early grades students should be exposed to the basics of agricultural production "what grows where, what is required for growth, how it gets to stores, and how modern agriculture compares to agriculture in other places and other times" (p. 183). In the middle grades, Benchmarks urges educators to help students learn by involving them in projects to trace food to its origin and to grow plants for food. In high school, once the basics are understood, students then learn of the complexities of the food and fiber system by examining the interdependent elements of the system: roads, telecommunication, weather, labor, prices, water availability and soil fertility.

Benchmarks suggests students are to know specific subject matter at four grade level groupings: K-2, 3-5, 6-8, and 9-12. Curricular expectations progress in complexity through the grades, paralleling the sequence outlined in the CALF. Benchmarks' treatment of the agri-food system is more critical than CALF and asks students at the high school level to evaluate the risks involved in the system. Also laudable is its continuous and progressive emphasis on the plant and animal pests and the problems associated with food spoilage.

b. Critique of science education's benchmarks for agriculture literacy

The curricular goals for education about the agri-food system made by science educators are well reasoned and balanced. However, we do not know if teachers in our schools and aspiring teachers being educated in our colleges and universities today have the requisite knowledge, understandings or experiences to facilitate the type of education suggested by Benchmarks (Raizen and Michelson, 1994; Carlsen, 1991). Most elementary teachers are uncomfortable setting up experiments and, for example, do not understand how fertilizers promote plant growth. It is not known if elementary teachers can trace the path that a food has traveled on its way to a grocery store or, if they can identify "hazards that food encounters from the time it is a seed until it reaches the kitchen" (AAAS, 1993, p. 184). Similarly, it is not known, as suggested by Benchmarks, if high school science, mathematics, social studies, and history teachers understand the "interactions, among production, preservation, transportation, communication, government regulations, subsides, world markets [and the] social side-effects and trade-offs of agricultural strategies" (AAAS, 1993, p. 186).

The notion of teaching through agri-food system examples is commendable. However, only a few teachers presently possess the agricultural knowledge, understandings and experience needed to teach in the manner suggested by the Benchmark curricular guide. Terry, Herring, and Larke (1992) found three-fourths of 510 Texas fourth grade teachers had low knowledge about agriculture. Humphrey, Stewart, and Linhardt (1994) discovered and concluded that:

> only 20 percent of University of Missouri-Columbia pre-service elementary education majors were confident to teach agricultural concepts. And with agricultural experience significantly related to confidence to teach concern as to the success rate of the presentation of the information about agriculture in the classroom becomes an issue (p. 29).

To teach students about the agri-food system, teachers must experience and understand its complexity. Based upon these findings, it appears that pre-service teachers do not possess the requisite understandings and experiences in agriculture to render a true-to-life portrait of the agri-food system.

4. Learning is change: educational psychology.

a. Learning theories

Learning is change. During change individuals are faced with altering the way they perceive and understand phenomena and their relationships with people and the world. Marris (1974) asserts that change is a very difficult process for most people, because they are often quite content with the way things are; they've grown accustomed to the way they see and understand. He further suggests that people possess a "conservative impulse" to maintain the status quo. Often it takes provocative situations to force readjustment of their way of knowing the world. This is not a pleasurable experience for most people.

For the first half of this century, the behaviorialist school of psychology ruled supreme. This line of thought suggested that people learned in systematic steps that could be reduced to incremental learning. The metaphor of the learning machine was used to conceptualize behaviorialist ideas. Later in the century, researchers in computer science, linguistics and cognitive psychology proffered a new way to conceptualize

learning. This new conceptualization involved two new notions of the way in which individuals structure the perceptions taken in from their interactions with the environment. These theories are called the constructivist theory and the conceptual change model. Eventually these related theories merged with the socio-cultural psychological theory advocated by an early 20th-century Russian named Vygotski.

The first theory came primarily from the work of Piaget (1950), a French scholar who emphasized the inherited processing complexes of the brain. He suggested that the brain can be thought of as a container of perceptions that are organized into different structures. These structures are modified as the person faces new and different sensory input. The brain seeks what Piaget called "equilibrium." Equilibrium is reached when functions (biologically determined processors) are influenced by the sensory inputs, a balance is achieved. As more input comes in, discontinuity in the previously developed structures occur forcing change. This change must be accommodated to form new structures within the brain. These structures, Piaget asserted, have sub-units called schemas (Moll 1990; Bereiter 1994). Schemas can be thought of as structures of interactions which are constantly changing. As these changes occur, a person learns by reconstructing his/her maps or schemas.

Related to Piaget's contructivist theory is the notion of conceptual change. This was first advanced by Kuhn (1963) in his seminal work <u>The Structure of Scientific Revolutions</u>. He argued that the idea of a systematic development of a scientific body of knowledge was wrong. Kuhn suggested that scientific knowledge development actually followed a less linear and regimented process. That is, scientists follow theories,

paradigms as Kuhn called them, for as long as they are fruitful. If they no longer make sense or if they became too cumbersome, they are dropped in favor of a new paradigm with a promise of more bountiful prospects for solving the puzzles of scientific inquiry. These ideas were adopted by Posner, Strike, and Gertzog (1982) and incorporated into their theory of conceptual change in science learning. They suggested that students abandoned their previously held conceptions only when they saw that their idea was no longer fruitful, became too cumbersome, and when the new idea offered the possibility of being more fruitful for answering their questions than their previous conception. Basically, the conceptual change model holds that people must be challenged to learn. Through challenges to previous ideas, the learners reconstruct their internal explanation for the world. Science educators (Smith, 1990; Driver, Guesne, and Tiberghien, 1985; Novack, 1983) sought to promote learning by trying to help students construct, or at times, reconstruct their cognitive structure through conceptual change.

Change in an individual's cognitive structures, it was argued, could be facilitated by providing learners with situations or phenomena that challenged the previously held conceptions--conceptual change theory. To do this, theorists advocated more social interaction. Many added Vygotski's (1962) theory to the constructivist model. Vygotski's theory brought notions of how people learned in non-school settings. He asserted that learning was promoted through social activity between the learner and others. His theory included the notion of the need for the use of language in learning and suggested that one of the best ways to acquire this language was by a learner's work with a more skillful person. Vygotski believed that all learners had a "zone of proximal

development" which could be enhanced by a more educated and skilled teacher. The net result of adding Vygotski's theory to Piaget's was a hybrid theory known as social constructivism.

b. Understanding the agri-food system: lessons from science research

In science education, Anderson and Roth (1989): Vellom, Anderson and Palincsar (1993) advocated social constructivism through research on student learning communities that emulated the social processes that scientists traverse as they hammer out theory. Driver et al. (1994) also advocates the use of social constructivism. They reiterate the notion of combining Piaget's theory of constructivism with Vygotski's theory of the social use of language as fruitful for learners.

Vygotski's theory is grounded in the use of oral language (Schiffrin, 1994; Cazden, 1988). Language, and its use in interaction, is a driving force behind learning, argued the socioculturalists. Rosebery, Warren and Conant (1992) describe learning science as a process of "appropriating scientific discourse." To become discursive in science, they argue, involves collaborative inquiry in the doing of scientific work. Together, conceptual change and sociocultural theories comprise the two dominant lines of contemporary research in science education. By infusing relevant findings from these theoretical perspectives into teaching practices, curriculum designers and teachers can help students understand the world in which they live.

c. Implications of conceptual change and sociocultural research for agri-food system literacy

One might question: What do conceptual change and sociocultural research have to do with agri-food system literacy? Previously, it was stated that Frick and Wilson (1996) define agriculture literacy as "a basic *understanding* of agriculture..." (p. 59). Science educators have long sought to determine understandings of the complex process in the life sciences that are inextricably linked to agriculture---notably photosynthesis and ecology. By analyzing studies in these two areas--the first by Anderson and Roth (1989) and the second by Hogan and Fisherkeller (1996)-- salient findings and methodologies can be employed in teaching and learning of agri-food system literacy.

Anderson and Roth (1989) illustrate the findings of conceptual change research. These types of findings can assist educators as they seek to help learners modify cognitive structures relative to the agri-food system. In the first study of middle school student conceptions of photosynthesis, Anderson and Roth (1989) found that students held naive conceptions or misconceptions about how plants acquire food. These conceptions were based on their personal experience with food; the consumption of something edible from the outside. Students, in turn, used this knowledge and applied it to plants, a reasonable application. They believed that roots consumed what they needed from the soil. In other words, plants ate soil to grow; food for plants comes from the outside environment.

For students to learn and accept canonical knowledge of science, students must grow through a process of conceptual change. They must be challenged by teachers to reject inaccurate beliefs about food and plants, replacing them with ideas in accord with communities of scientists who describe the world. Anderson and Roth (1989) suggested "without this involved process of restructuring and integration of personal knowledge with scientific knowledge, students cannot be successful in using knowledge about photosynthesis to make reasonable predictions and explanations of real-world phenomena" (p. 278).

What are the implications from the Anderson and Roth study for teaching and learning in agri-food system literacy? Trexler (1997) found that elementary students with limited exposure to agricultural production believed that farms were small (about 2 football fields), grew multiple varieties of crops in rows next to one another, and were tended by one farmer. This conception of a farm does not match the realities of large-scale, modern monocultural agriculture. From this embryonic study arises additional questions about what conceptions and misconceptions students hold about the agri-food system.

In a study that also explored understanding of the biological basis of food, Hogan and Fisherkeller (1996) employed a bimodal coding scheme to represent fifth and sixth grade student thinking about food chains in ecosystems. Student pairs were interviewed and their ideas recorded. The sophistication of student thinking about a given topic was judged for subconcepts in ecology along two dimensions: quality (compatibility) and depth (elaboration of response) by comparison with expert propositions. During these interviews, students were asked questions related to major ecological components which were broken down into three subconcepts: food chains, decomposition, and basic nutrient

cycling. This study found that when compared to experts, the majority of students, after instruction, held compatible, but sketchy understandings about food chains. Those who held no conceptions prior to the ecology teaching unit profited most from instruction, perhaps because they held less developed mental schemas to hinder the construction of a new understanding of food chains. Hogan and Fisherkeller (1996) pointed out that specific ecological subconcepts undergird larger concepts and without this foundation understanding cannot be built. For example, "students are unable to generalize that all organisms depend on the green plants that are the producers at the base of food chains. This relates to their lack of understanding of food as an energy-containing material, and of how solar energy is transformed to chemical energy during photosynthesis" (Hogan and Fisherkeller, 1996, p. 959).

It is evident that conceptual change theory and the use of interviews to determine what understanding people hold can be applied to agri-food system concepts. Currently there is no research that looks at elementary students. Similarly, there is dearth of knowledge about what prospective elementary educators understand about the concepts they are expected to teach relative to accepted, scientific curricular guidelines for the agri-food system. Curriculum materials then are developed that are based on what people believe students and prospective teachers need to learn, rather than what has been determined through a rigorous research protocol. Until researchers determine commonalties among agri-food system conceptions, curriculum developers and teacher educators in colleges and universities may concentrate their efforts on content that may be

already understood, while ignoring, or possibly not challenging, misconceptions that impede the construction of a scientifically accurate schema for the agri-food system.

Summary

This summary review of the literature suggests that the majority of people in the US are ignorant of how their eating habits affect the environment. They are unaware of the unsustainable nature of the agri-food system, because so few are educated about the trade-offs of the modern, industrially-based system which is predicated on extracting short term profit from the earth.

Concerns arise as to the democracy's role in the use of science and technology. Some philosophers of science suggest that a hegemony exists in society that allows for the blind use of technology. Others suggests that networks of elites govern science in a fair and equitable manner that is in keeping with the evolved nature of democracy, while other social scientists question the private control of science. Ultimately though, society through the election of elites, the decisions made in the market, or through direct participation in politics, chooses the direction of scientific research or technological application.

Understanding how people make choice decisions is important when designing educational programs that are designed to help people weigh trade-offs among technologies. Additionally, understanding how and when people band together for joint

action is desirable for educators seeking to instill a sense of empowerment in students with regard to agricultural and environmental issues.

Agricultural and science education policy makers are concerned about this lack of understanding, but for different reasons. Agricultural educators, mainly affiliated with colleges of agriculture in land-grant universities, seek to inform the public of the wonders of the system's productivity and reassure them of its wholesomeness. Science educators are interested in helping people understand the technological, environmental, and cultural trade-offs inherent in the modern system. Certainly there are merits in understanding each of these viewpoints. However, picture--representative of both perspectives--and inclusive of the concerns of sociologists, environmentalists, and philosophers, best serves consumers in accurately evaluating the system .

To promote this understanding, educational efforts are needed at both the K-12 and post-secondary levels to: 1) determine what conceptions learners hold of the agri-food system, 2) increase pre and inservice teachers' understanding and comfort with the topic, and 3) develop agri-food system educational materials, curriculum, and experiential learning activities to build upon, enhance, and even counter conceptions held by learners. Until researchers and curriculum developers understand what conceptions students and prospective teachers hold, little progress can be made in improving the understanding of the agri-food system. This dissertation begins to lay a foundation upon which to build a bridge to connect those in agricultural and science education as they raise public consciousness of the modern agri-food system. With this consciousness, individuals in society can democratically construct the type of institutions within the agri-food system that they most value

III. METHODOLOGY

A. Introduction to Method

This exploratory qualitative study's purpose is to determine elementary students' and prospective elementary school teachers' understandings of concepts foundational to an understanding of a sustainable agri-food system. Specifically, the study assessed informant understandings of specific educational benchmarks created through a synthesis of Benchmarks for Science Literacy (AAAS, 1989) and the California Agricultural Literacy Framework (Leising and Zilbert, 1994). Sixteen benchmarks were used to structure the conversation between the researcher and the informants. Elementary students were asked to discuss their ideas about thirteen benchmarks, while prospective teachers were asked about these thirteen as well as three additional, higher-level benchmarks. To frame the analysis, detailed concept maps that represented ideal, expert conceptions of the benchmarks were devised. Comparisons were then made between the expert concept maps and those developed by the researcher that represented the informants' understandings.

This chapter begins with a rationale for the selection of the methods used in this study. This rationale is novel to the field of agricultural education, although it is commonplace in other fields of education, most notably, science. Next, key concepts, benchmarks, and related vocabulary that frame the study are presented. Benchmarks and vocabulary are then integrated into a model expert conception represented through a concept map in the body of the paper. This serves as an example of how they were used as an analytic tool. The remainder of the concept maps are found Appendix C. Narratives are then provided for all benchmarks which are grouped according to logical associations of benchmark conceptions. The remainder of the chapter describes the details of the research procedures for data collection and analysis. The chapter concludes with a brief summary of the methods.

B. Rationale for Selection of Method

AAAS (1993) suggests that researchers have not assessed student knowledge and understandings of technological systems, nor do they understand how students learn about them. The association comments:

> although extensive research has focused on survey evaluations of technology programs or on student attitudes toward technology, there is only a small body of research on what students know and how they learn about concepts and systems on technology (p. 349).

This statement supports my argument regarding research in the agricultural education field, particularly with respect to the impact of this technological system on the lives of citizens. For the most part, agricultural literacy research has been limited by survey research and has not focused on determining what people understand or how they learn about the agri-food system. This narrow focus springs from both a historical research emphasis on skill preparation for employment in the agricultural sector and an over-reliance on quantitative methods. As a result, many questions related to teaching and learning in agricultural education have not been addressed. On a broad scale, these questions include, but are not limited to: 1) How do people learn about the agri-food system? 2) What impact does the formal educational system make in developing student understanding of the agri-food system? 3) What do people understand about the agri-food system? 4) How can the ability of the citizenry to critically evaluate the trade-offs inherent in the modern agri-food system be enhanced?

On a practical level, the use of the qualitative methods can produce tools for understanding. By this I mean teachers or curriculum designers can draw from cases illuminated in this study to better understand students that are similar to those they teach or to those for whom they design curriculum. This study's in-depth qualitative findings may have more merit for these groups than generalizations about abstract and remote populations.

The agri-food system is a complex assemblage of interrelated networks. To develop theory on how people come to understand this system, and then to design educational materials and programs to help people make well-reasoned decisions about it, requires ferreting out idiosyncratic understandings of a few, well selected persons. Representing such understandings can best be accomplished by the use of qualitative methods, because they allow for a detailed examination of the cognitive structures of individuals.

This quest for understanding calls upon insights from the fields of sociology of knowledge, cognitive anthropology, and linguistics. Mannheim (1929) argues that "there

are modes of thought which cannot be adequately understood as long as their social origins are obscured" (p. 1). Humans, as social beings, use "language as the primary shaper of meaning" (Fine, 1990, p. 129). Frake suggests, as did Piaget, that the way to unearth mental constructs and schemata of individuals is to analyze speech. Frake (1980) argues that "talk exemplifies a conceptual unit whereby we organize our strips of experience in formulating accounts of what is happening, our memories of what has happened, and our perceptions and plans for what will happen" (p. 57). Cazden echoes and pares down this idea by stating that "speech unites the cognitive and social" (p. 1). These cognitive and social aspects of learning were discussed earlier in this study as two dominant lines of research in learning theory.

These two theoretical lines of thought have not been well integrated into the field of agricultural education, as evidenced by its almost exclusive reliance on quantitative research techniques. The methodology used in this study included both cognitive psychology and socio-linguistics as frames for analysis. As mentioned in chapter two, agricultural educators argue that literacy requires one to possess an "understanding" of the food and fiber system. However, their research methods do not allow for detailed evaluation of idiosyncratic thought. Considering this limitation, I drew upon research methodologies from outside my field and employed techniques that surfaced understandings of the agri-food system. To interpret participant's meaning, discourse analysis was used as a lens for analysis of interviews.

Specifically, to gain the richest data from each exchange, I employed focused interview techniques (also called clinical interviews by educational researchers and psychologists) (Merton, Fiske and Kendall,, 1952). Merton et al. suggest that a focused interview differs from other interview techniques because the interviewer has previously analyzed many aspects of the subject prior to the interview. As a result,

> . . . the interviewer can readily distinguish the objective facts of the case from the subjective definitions of the situation. He is thus alerted to the patterns of selective response. Through his familiarity with the objective situation, the interviewer is better prepared to recognize symbolic or functional silences, distortions, avoidances, or blockings and is, consequently, better prepared to explore their implications. The prior analysis thus helps him detect and to explore private logics, symbolism and spheres of tension. . . . Finally, prior content analysis facilitates the flow of concrete and detailed reporting of responses. Summary generalizations by the interviewee mean that he is presenting, not the raw data for interpretation, but the interpretation itself. . . . Furthermore, when subjects are led to describe their reactions in great detail, there is less prospect that they will, intentionally or unwittingly, conceal the actual character of their responses (p. 4).

In the case of this study, selected benchmarks--formed by synthesizing benchmarks from Benchmarks and CALF--are analyzed in detail. These benchmarks come from a framework developed as a component of my comprehensive examination in science education (Appendix B). The following section of this paper articulates expert understanding of this synthesis.

C. Benchmarks for Study

Selected benchmarks from the Synthesis of the Benchmarks for Science Literacy and the California Agriculture Literacy Framework (Tables 1 and 2) were assessed in this study. The key concepts are based upon the CALF and lay out general lines of questions relative to the agri-food system. Benchmarks identify specific goals for learners, while the language section lists vocabulary that would most likely be used during oral discourse about the benchmarks. Listed within the Benchmarks section are the grade levels where the AAAS Benchmarks and the CALF suggest that the subject be taught.

Table 1. Agri-food System Key Concepts, Benchmarks and Language for Elementary Students

Key concepts	Benchmark	Language
I. Agri-food System		
A. What is agriculture?	1) Identify food and fiber products that come from plants and animals. (K-1 CALF and K-2 AAAS)	food, fiber, wood
	2) Describe the variety of farms and their products. (K-1 CALF and K-2 AAAS)	small, large, family, corporate, farms, structure
	3) Describe the journey of a food or fiber product travels from the farm to the consumer. (2-3 CALF)	research, production, transportation, processing, marketing, distribution, consumption
	4) Describe how agriculture uses natural resources to provide peoples' basic needs. (4-5 CALF)	soil, air, water , energy
II. Science: Agricultural - Environmental Interdependence		
A) How are parts of the ecosystem managed by humans related, and how do they interact?	1) Describe how crops depend on an area's climate and soil for growth. (3-5 AAAS and CALF 4-5)	temperature, dependent, habitat, soil, precipitation
B) How do humans	1) Describe basic growth	light, air, water, food,

manage crops to promote growth?	requirements for plants and animals. (K-2 AAAS and 4-5 CALF)	space, warmth, soil
	2) Describe how crops may be lost to pests. (K-2 AAAS)	pest, damage, loss
	3) Explain how crops are protected from weeds and pests. (3-5 AAAS and 4-5 CALF)	kill, poison, crop protection, chemicals, pesticides, poisons, barrier
	4) Describe the positive and negative impacts of using poisons to protect crops. (3-5 AAAS)	poisons, resistance, harmful, beneficial , costs, profit, positive, negative, labor, resistance, disease, increase, decrease
C) What is the role of science and technology in the food and fiber system?	1) Explain why irrigation and fertilizers are used to grow crops. (3-5 AAAS and 4-5 CALF)	nutrients, soil, water, dry, increased production, arid, wilt
	2) Identify the places of origin of common foods eaten by Americans. (3-5 AAAS and 4-5 CALF).	state, United States, countries, world
	3) Describe how places too cold or too dry to grow certain crops can obtain food from places with more suitable climates. (3-5 AAAS and 4-5 CALF)	trains, cargo planes, trucks, transportation, ships, climate, cold, dry, food
III. Cultural-historical		
A. How has the agriculture changed society.	1) Explain the affects of modern technology on farms, farmers and rural and urban communities. 4-5 CALF and 3-5 AAAS)	machines, fewer farms, agriculture, farmers, efficiency, pollution, loss of jobs and culture, increase time, inexpensive food, dependence, complexity

Table 2. Synthesis of Prospective Teacher Benchmarks of Benchmakrs for Science Literacy and the California Agriculture Literacy Framework

Key concepts	Benchmark	Language
II. Science: Agricultural - Environmental Interdependence		
A. What is the role of science and technology in the food and fiber system?	1) Describe how new varieties of farm plants and animals have been engineered to produce new characteristics. (9-12 AAAS)	genetic engineering, cloning, natural selection, multiple births, gene transfer, seedstock
III. Historical Cultural		
B. How has the modern agri-food system impacted society	1) Explain how agricultural technology changed the way people live and work in the US over the last century. (9-12 CALF and 9-12 AAAS)	farms, urban, rural, population, society, shift, employment, increased production, time, manual labor, food variety
	2) Describe trade-offs inherent in the use of agricultural technology in terms of environment and human culture. (9-12 CALF and 9-12 AAAS)	increased production, sustainability, land degradation, environmental harm, higher disposable income, pesticides, fertilizers, employment, pollution , loss of culture, preservation, erosion, risk, petroleum use, inexpensive food

D. Model Concept Map - A Tool for Comparison

To generate concept maps of benchmarks that would most logically link to conversations carried out during the interviews--and also that represent concepts and related sub-concepts--multiple benchmarks are grouped on single concept maps. In one

case, because of the complexity of the topic (pesticides) cognitive associations, most logically represented on one page, were placed on two pages because of paper size limitations. Multiple colors are used in the maps to distinguish concepts that are fundamental and those that form sub-concepts. The sub-concepts are represented on multiple maps, hence the use of multiple colors. This helped to determine the underpinning nature of select benchmarks with regard to other benchmark understandings.

It is important to note that, because the interviews were focused on the lettuce and meat found in a McDonalds™ Big Mac™ , the concept maps are related to these specifics concepts. For example, in benchmark *I.A.I. Identify food and fiber products that come from plants and animals* (Figure 1)--the concept map reflects the origin of lettuce as being from a plant. In this way, the Big Mac's™ lettuce and meat were used to create a context for discourse and a basis for concept maps. A definitive concept map for all possible crops and their origins is not the intent of these maps. Rather, for the most part, they, illustrate content that is specific to the context of the BigMac™.

To model the basis for comparative analysis, one example of a concept map is presented (Figure 1.); the remainder can be found in Appendix B Figures 2-11. Following the map is a narrative. After this narrative of the model, tables list key concepts, benchmarks and language expected in discourse. These are grouped in logical relationships based upon the key concept as they are found in the expert concept maps.

E. Elementary Student Expert Benchmark Conceptions

Figure 2. Expert Concept Map for Elementary Key Concept: What is Agriculture?

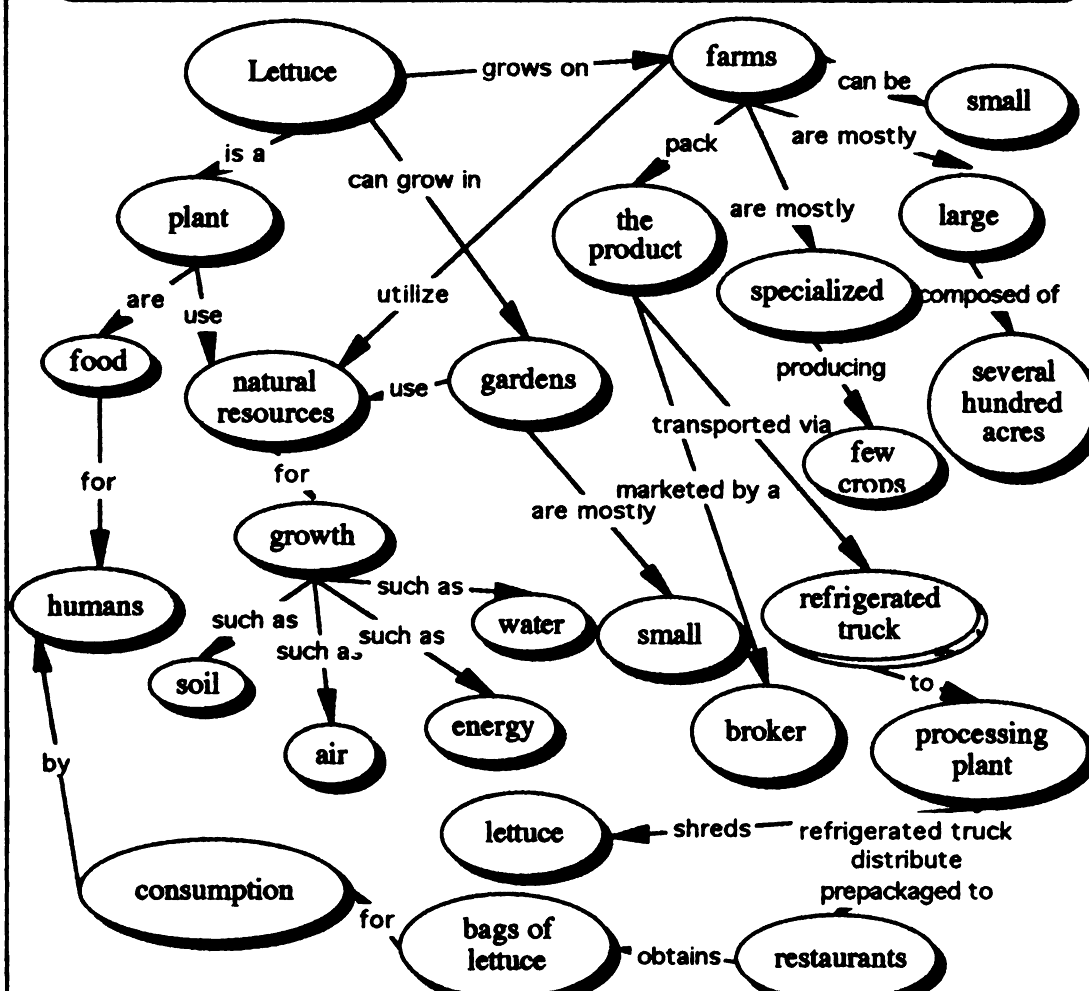
Figure 1. Concept Map for the Expert Key Concept: I.A. What is agriculture? Bencmarks 1-4.

I.A.1 Identify food and fiber products that come from plants and animals.

I.A.2. Describe the variety of farms and their products.

I.A.3 Describe the journey of a food or fiber product as it travels from farm to consumer.

I.A.4 Describe how agriculture uses natural resources to provide peoples' basic needs .



Narrative: What is agriculture?

Figure 2 graphically portrays the four benchmarks and their interrelationships relative to answering the guiding question-- "What is agriculture?." To understand these benchmarks, one must understand that lettuce is a plant and that plants are food for humans. In order to grow, plants require natural resources such as, soil, air, water and energy in the form of sunlight for growth. Humans typically grow lettuce in two locations: farms and gardens. Gardens and farms are places where the lettuce acquires needed natural resources. Gardens typically are thought of as small plots of land where, oftentimes, a small amount, but a diverse group of crops is grown. On the other hand, modern farms in the US are typically very large. Most lettuce farms are in excess of hundreds of acres in size. These farms are highly specialized and employ monocultural techniques and specialists for insect and weed control, irrigation, and fertilization. Interestingly, lettuce for all the US McDonalds™ restaurants comes from only four to five growers (F. G. Gonzales, personal communication, March 8, 1999).

The interconnected system that moves food from the fields to the consumer is highly complex. In terms of fresh produce, it is complex, but nowhere near as complex as a product, bread for example, that is combined with various other commodities to make food with ingredients from multiple sources. Lettuce, then, is a simple, yet illustrative example that can be used to show the journey that a food product travels from farm to consumer.

The lettuce is picked and placed into large trucks and shipped to a centralized processing plant where it is washed, shredded and placed into plastic bags. The bags of lettuce are then transported via refrigerated trucks to geographically centralized distribution centers throughout the US. When lettuce is needed, orders are placed by local restaurants, and refrigerated trucks deliver the bags of lettuce to the restaurants where it is later placed on a BigMac™ for consumption. Benchmark I.A.4 is described with the next benchmarks.

Table 3 Benchmarks for II. Science: Agricultural-Environmental Interdependence: A. How are parts of the ecosystem managed by humans, and how do they interact?

Benchmark	Language
1) Describe how crops depend on an area's climate and soil for growth.	temperature, dependent, habitat, soil, precipitation,

Narrative: Climate and Soil

In order to understand the benchmark in Table 3, one must understand that animals and plants are living things that require natural resources. These resources are found within specific habitats for growth and maintenance such as, soil, air, energy (in the form of carbon-based food for animals and in the form of sunlight for plants), and water. This requirement for natural resources is found also in Benchmark I.A.4. and is foundational to comprehending numerous other benchmarks (II.A.1., II.B.1, II.B.2., II.B.3., II.B.4, II.C.1., II.C.2., II.C.3.). It is noteworthy that the need for natural resources, as a requirement for growth of living things, undergirds so many other benchmarks because they are the foundation for plant and animal growth.

To grasp this benchmark, one must also understand that humans grow crops--animals and plants--to meet their requirements for energy and that crops are dependent upon climate (precipitation, seasonal temperatures, hours of daylight, and wind) and soil (minerals, water holding capacity, substructure for support, etc.) for their growth.

Table 4. Expert Concept Map for Elementary Benchmarks: II. Science, Technology and Environment--B. How do humans manage crops to promote growth?

Benchmark	Language
1) Describe basic growth requirements for plants and animals.	light, air water, food, space, temperature, soil

Narrative: Basic Growth Requirements for Plants and Animals

To understand the benchmark in Table 4, in addition to grasping the role natural resources play in relation to living things (see Benchmark I.A.6.), one must also know that plants and animals require specific environmental conditions such as space and temperature for growth.

Table 5. Expert Concept Map for Elementary Benchmarks: II. Science, Technology and Environment–B. How do humans manage crops to promote growth?

Benchmark	Language
2) Describe how crops may be lost to pests	pest, damage, loss, weeds, insects, rodents
3) Explain how crops are protected from weeds and pests.	kill, barriers, pesticides, chemicals, barriers, organic, inorganic
4) Describe the positive and negative impacts of using poisons to protect crops.	increased production, sustainability, land degradation, environmental harm, higher disposable income, pesticides, employment, pollution, risk, petroleum use, inexpensive food

Narrative: Human Crop Management

The benchmarks in Table 5 are closely tied together. As a result, they are dependent upon the understandings of interrelated sub-concepts. For example, as cited previously, requirement for plant and animal growth and the need for natural resources undergirds understandings of competition. Pests are competitors with crops that humans selectively grow for these basic needs. Weed pests limit growth by limiting space for growth and by taking up nutrients from the soil. Insects lay eggs in crops and feed upon crops, while rodents may feed directly upon crops as a source of their food or may spoil crops by nesting and excreting waste in them.

Humans protect crops by creating barriers to pests, killing them, or preventing them from completing their life cycle. In the case of rodents, deer, or even weeds, humans create barriers that prevent pests from eating crops directly or by preventing them from obtaining the natural resources (water, soil, etc.) necessary for them to live. In addition to barring them from obtaining natural resources, humans kill pests directly with pesticides. They do so by poisoning them with organic materials such as pepper, chrysanthemums or with inorganic materials derived from various sources, but predominantly with petroleum-based chemicals. Pests can also be reduced in a habitat by preventing them from completing their life cycle. For example, humans can manage livestock grazing habits so that the animals do not eat in areas were internal parasites eggs are present, thereby preventing the parasites from entering the hosts. The eggs cannot survive indefinitely, so they die from lack of a host.

As with all technologies there are trade-offs and risks associated with the use of pesticides; they are poisons used by humans to ward off and kill animals and plants. There are positive and negative impacts of using such materials. Some negative impacts include, but are not limited to: 1) the economic costs to the farmer and the ultimate consumer, because pesticides are expensive to purchase and equipment for their application is costly, 2) pests often develop resistance to pesticides, thereby necessitating the development of new--sometimes even more toxic--chemicals. In addition humans may become dependent upon a particular pesticide to which pests later become resistant, 3) the improper use of pesticides may lead to contamination of the environment, most notably the soil, water, and air--possibly leading to morbidity and death to living things, and finally, 4) an over-reliance on the use of pesticides may decrease sustainable agricultural practices (crop rotation, for example) resulting in an overall long term decrease in fertility of the land.

On the other hand, there are positives associated with the use of these poisons. These include, but are not limited to: 1) a reduction of labor involved in the production of food, thereby providing for a variety of employment opportunities and an increase in producer time for other productive endeavors, 2) an increase in yield of food, resulting in cheaper food for consumers, greater disposable income and increased profits by some farmers, and 3) a decreased likelihood of food-borne disease, contributing to higher levels of human health.

Table 6. Expert Concept Map for Elementary Benchmarks: II. Science, Technology and Environment--C) What is the role of science and technology in the food and fiber system?

Benchmark	Language
1) Explain why irrigation and fertilizers are used to grow crops.	nutrients, soil, water, dry, increased production, arid, wilt, chemicals

Narrative: Irrigation and Fertilizers

Table 6 lists the benchmark for irrigation and fertilizers as well as language that a person speaking about the topic would most likely use. In order to explain why irrigation and fertilizers are used to grow crops, one first needs to understand the requirements for growth in plants (Benchmark I.A.4 and II.B.1). One needs to understand that soil--

particularly in reference to its fertility and composition--and water are natural resources required for plant growth. From this basis, one can comprehend the reasons why fertilizers and irrigation are used.

Humans increasingly grow crops on unsuitable or marginal land in areas where the temperature is conducive to plant growth. This enables them to obtain crops throughout the year, not simply when they are seasonally available local geographic regions. Growing crops in these regions requires humans to manage and control environmental factors such as water and soil fertility.

Water is a constant requirement for crops. To supply water, humans design technological systems that deliver it to their crops. Irrigation becomes increasingly important as humans use land in deserts to grow foods throughout the year, because the precipitation in these areas is not adequate to maintain crop growth. This human made system--composed of machinery, wells, dams, aqueducts, etc.--then supplies water on a consistent basis, thereby allowing producers to increase production of the crops they deem desirable.

Humans use other systems to deliver fertilizers to increase plant growth. Fertilizers--organic or inorganic in origin--are applied to the soil or in water for delivery to plants. Nutrients, primarily minerals, are then taken up by plants through roots. The use of inorganic fertilizers has, for the most part, replaced organic and is of increasing importance as more marginal land is used for crop production and as humans grow the same crops year-after-year on the same land. By growing the same plants on land for consecutive seasons, the soil becomes depleted of nutrients from lack of crop rotation.

As a result of these monocultural practices, soil fertility decreases and producers require additional fertilizers to sustain crop yields.

Table 7. Expert Concept Map for Elementary Benchmarks: II. Science, Technology and Environment--C. What is the role of science and technology in the food and fiber system?

Benchmark	Language
2) Identify the places of origin of common foods eaten by Americans.	state, United States, countries, world
3) Describe how places too cold or too dry to grow certain crops can obtain food from places with more suitable climates.	trains, cargo planes, trucks, transportation, ships, climate, cold, dry, food

Narrative: Origin of Foods

Table 7 identifies the benchmarks related to identifying origins of foods eaten by Americans and how people in inhospitable climates gain foods from more favorable places. Humans have designed complex technologically-based systems that bring food production to them from across the globe. Humans living in unsuitable climates (either too cold or too dry) obtain food from places with more suitable climates where the crops can be grown. Growing crops in warmer or dryer regions often necessitating the use of irrigation and fertilizers (See Benchmark II.C.2. In addition, dry climates are often too hot to grow crops that require temperate or cool growing conditions. To transport crops from these distant locations to consumers who demand them, humans have designed

complex networks that move food and fiber products around the world. The networks include: roads, canals, and rivers, as well as vehicles like trucks, ships, trains and planes. In addition, the networks are designed by human actors.

Specifically related to the context of the interview, winter lettuce-- found on a Big Mac™ made in a restaurant in East Lansing, Michigan--is transported from warmer, arid climates (western US and Mexico) to the US Midwest. It makes its journey via refrigerated trucks that slow spoilage. The other focus of interviews, beef, because it is less perishable and has a higher value per pound, can be shipped great distances. Beef is often shipped to the US from places like Central and South America and Australia. Beef used in a McDonald's™ hamburger, however, comes from North America exclusively (Gonzales, 1999), although its geographic origin is nearly impossible to pinpoint because beef cattle are raised in all US states and all Canadian provinces.

Table 8. Expert Concept Map for Elementary Benchmarks: III. Historical-Cultural--C. How has agriculture changed society?

Benchmark	Language
1) Explain the affects of modern technology on farms, farmers and rural and urban communities.	machines, fewer farms, agriculture, farmers, efficiency, pollution, loss of jobs and culture, increase time, inexpensive food, dependence, complexity

Narrative: Affect of Modern Technology of Farms, Farmers and Communities

Table 8 lists the benchmark related to the effects of modern technology on farms, farmer and communities. As humans employ technologies to produce food and fiber, farms, farmers, and rural and urban communities are affected. Farmers use machines and other technologies that decrease the amount of labor required to produce crops. As a result, farm size increases while their numbers decrease, as well as the number of farmers. Farmers become increasingly dependent upon these technologies and tend to specialize in the type of crops they produce. In turn, technology becomes increasingly specialized and increases in its complexity. Farms generally are more complex than in the past. Laborers require more training to operate increasingly complex technologies that are purchased at higher prices by farmers, thereby increasing their need for capital.

Along with farms and farmers, rural communities change. Fewer people work on farms, so more people move to urban centers for employment. Increased efficiency of technology affects the structure and size of rural families--more women enter the work force and the number of children born decreases; this change is also evident in urban centers. Additionally, urban centers are affected by their reliance upon rural communities for food. They, for the most part, are no longer connected directly to the production of food. This freeing up of time nets those in both the rural and urban communities greater opportunity for other productive endeavors; food becomes less costly to produce and purchase. However, this reliance upon technology also decreases firsthand knowledge, thereby mediating human relationships with and connections to their environment.

F. Prospective Elementary Teachers Benchmarks Conceptions

Additional interview questions for prospective teachers--beyond those designed for elementary students--were based concepts, benchmarks and vocabulary found in Table 2. These understandings are expected of high school students at graduation and are seen by both the authors of Benchmarks for Science Literacy and CALF as defining one who is agri-food system literate.

Table 9. Expert Concept Map for Prospective Elementary Teachers Benchmarks: II. Science, Technology and Environment--A. What is the role of science and technology in the food and fiber

Benchmark	Language
1) Describe how new varieties of farm plants and animals have been engineered to produce new characteristics.	genetic engineering, cloning, natural selection, multiple births, gene transfer, seedstock

Narrative: Engineering of Farm Plants and Animals

Table 9 lists the prospective elementary teacher benchmark and vocabulary related to the engineering of farm plants and animals. Humans engineer plants and animals to produce characteristics that they value. Most often this comes in the form of greater productivity--yield per acre, disease or pest resistance in plants--or in livestock--feed efficiency or carcass yield, for example. The designing of plants and animals by humans for specific characteristics is not new. Humans have selected plant and animal seedstock

with desired qualities for thousands of years. They then bred these superior animals to other animals in an attempt to improve specific, desired characteristics. Today, however, humans have--with the use complex technologies--begun to make quantum leaps in the manipulation of genetic material. For instance, genetic engineering in farm animals and plants now employs technologies such as cloning, embryo and the more complex, gene transfer. The use of these technologies has the potential to increase output of both farm plants and animals, but they also push the limits of acceptance by some in society.

Table 10. Expert Concept Map for Prospective Elementary Teachers Benchmarks: III. Historical and Cultural--A. How has the modern agri-food system impacted society?

Benchmark	Language
1) Explain how agricultural technology changed the way people live and work in the US over the last century.	farms, urban, rural, population, society, shift, employment, increased production, time, manual labor, food variety

Narrative: Agricultural Technology's Influences on US Lives and Work

Table 10 provides the benchmark and vocabulary for agricultural technology's influence on the way people live and work over the last century. Over the last one hundred years in the US, agricultural technology has increased crop production, increased the variety of food choices to consumers and provided alternatives for food transport, storage, distribution, processing and preparation. These changes are primarily the result

of technologies that reduced labor requirements within the entire agri-food system, netting a reduction in time spent getting food to the table and fiber products to their end-user. As a result, fewer people--approximately 50% at the turn of the century compared to 1.7% today--produce the food and fiber for the rest of society. (It is true that currently nearly 20% of the US workforce is, in some way, employed within the agri-food system.) This transition has resulted in a decline in rural and an increase in urban populations. In other words, people have moved from the farms to the cities. With this move has come a disconnection with the land--a form of unconsciousness--and a resulting fear of the system's inherent risks. Additionally, the reduction in time allowed society to devote more resources to other productive endeavors and, at the same time, altered employment opportunities throughout society. This shift has led to a decline in production-related employment and an increase in service-related occupations within the agri-food system; these changes mirror other sectors of society.

Table 11. Expert Concept Map for Prospective Elementary Teachers Benchmarks: III. Historical and Cultural--A. How has the modern agri-food system impacted society?

Benchmark	Language
2) Describe trade-offs inherent in the use of agricultural technology in terms of environment and human culture.	increased production, sustainability, land degradation, environmental harm, higher disposable income, pesticides, fertilizers, employment, pollution , loss of culture, preservation, erosion, risk, petroleum use, inexpensive food

Narrative: Trade-offs of Agricultural Technologies

Table 11 provides a benchmark and vocabulary related to the trade-offs in the use of agricultural technologies. Agricultural technology has trade-offs as do all human-designed technologies. These technologies cause both positive and negative consequences for the environment and for human culture. Agricultural technologies influence the environment by altering the natural habitat, which in turn forces living things within it to either adapt or die. Humans alter the diversity in the environment by, for example, eliminating "pests" that inhibit the growth of certain valued crops, changing the topography, creating systems for water delivery and food transport, or engineering plants and animals to meet specific parameters. The goal of these technologies is to increase the efficiency and reduce time and labor inputs in all aspects of the agri-food system. By doing so, human culture is altered. It becomes dissociated from the land as demographics shift from rural to urban. Food becomes cheaper to produce and less expensive to purchase, thereby increasing disposable income for the purchase other consumer goods, thereby altering employment opportunities as well as the overall economy.

With this technological revolution come additional trade-offs. First, there is an increase in large scale societal risk. As the system becomes increasingly centralized, there is greater likelihood that one isolated event can result in catastrophic consequences for many dependent upon the modern agri-food system. For example, with meat being processed at fewer and fewer sites--to maximize economies of scale--there is greater chance that the effects of microbial contamination would spread quickly throughout a geographic region. Similarly, if pesticide-laden lettuce--produced by only five to six growers for McDonalds™--was distributed throughout the country, the effect could be widespread, rather than a localized, isolated event. Finally, the industrialized agri-food system is dependent upon petroleum for its operation--tractor operation, inorganic fertilizers, pesticides, transport, storage, refrigeration, processing, etc.--consequently humans often unwittingly contribute to the depletion of this finite resource and to the pollution of the environment that its use produces.

G. Population

This study draws upon two distinct populations: upper grade level elementary students and their prospective teachers. Nine[1] (9) fifth grade students were purposefully selected for study. Fifth grade students were selected as informants, because they: 1) have reasonably well developed language skills, 2) are typically still classified as elementary students, and 3) fall into a grade that is defined within the agri-food system benchmarks. Their selection was based upon: type of school attended (private, public, charter, middle, elementary), gender, socio-economic status, geographic location of residence, and ethnicity. Once elementary students were selected, I mailed letters (Appendix F) describing the study and release forms to administrators of the school and the participating student (Appendix G). I emphasized to the administrator and teacher

[1] A sample of nine (9) students and nine (9) aspiring teachers were selected based upon Dr. Andy Anderson's recommendation (my committee's science education expert).

that typical students meeting certain parameters were sought. For example, I asked that certain schools provide groups of informants meeting specific backgrounds. Those from Detroit were selected based upon qualification for the Federal School Lunch program, a measure of poverty. Students in the urban Lansing areas were selected based upon their lower-middle-class status, while suburban Lansing students were from upper-middle-class families. Both guardian and students signed the elementary school release forms, while only the students did for prospective teachers. A $6.00 honorarium was provided for participation in the study.

The second group--nine prospective elementary teachers--was volunteer third and fourth elementary education students. One of these informant's video tape was indecipherable, therefore only eight (8) people comprised the teacher group. Prospective teacher selection was based upon educational background. Only one student participating in this study minored in science, I sought students who had little or no science background as they are representative of most elementary educators.

Letters describing the study were distributed to elementary education majors who were enrolled in Michigan State University's (MSU) Agricultural and Extension Education's (AEE) "Issues in Agricultural and Environmental Education" course; a course I taught. These students were asked to solicit participation of other elementary education majors that they knew. No student enrolled in the class participated in the study. In addition, I visited four (4) elementary education teaching methods courses to seek participants. Participants in the teacher group came from both these sources--five (5) from the AEE students and four (4) from the methods courses. I anticipated that a

$6.00/hour stipend would draw MSU students to the study--this was not the case. I increased the stipend to $20.00 and had more than enough volunteers. All prospective elementary teachers read a letter explaining the study and signed a consent form (Appendix H).

H. Data collection

Clinical interviews were used to elicit informant understandings of the agri-food system and to identify cognitive structures and the states of cognitive development (Novack and Gowin, 1984; Posner and Gertzog, 1982). The interview is widely accepted as a research tool to externalize conceptual or structural knowledge (Jonassen, Beissner, and Yacci, 1993). Each interview took approximately 45 minutes. During this time, approximately five minutes were spent determining demographic background; the remainder probed agri-food system understandings and in-school learning about food. Interviews were videotaped and transcribed, because they served as the primary data sources. Field notes and products created by the informants were consulted as secondary data.

I. Interview Questions and Protocol

Interview protocols were designed to ferret out elementary student and prospective elementary teacher conceptions relative to specific parts of the agri-food

system. Questions and protocol were reviewed by members of Michigan State University's (MSU) Departments of Teacher Education and Agricultural and Extension Education. To ground conversations in a familiar context, interviewees were provided a BigMac™ cheeseburger. I hoped that by starting with this familiar basis, informants could more easily express their ideas about the steps this familiar food goes through on its way from production to consumption.

Interviewees were asked to separate the cheeseburger into its component parts so that the complex food could be more easily analyzed. I then asked the informants to explain how the cheeseburger's "parts" arrived at the fast food restaurant or, if they felt more comfortable, to trace back the "parts" to their origin. Questions required interviewees to trace back only the lettuce and meat to their origin; these two foods are the least processed of the Big Mac's™ components and were easiest to trace. Further questions probed informant understandings of the structure of a farm; technologies used in food production, transport and distribution and their affects on society. Interviews concluded with questions addressing student memories of food and food production promoted through formal instruction in school. A complete list of interview prompts is found in Appendix E.

J. Analysis of Data

In this study, three different strategies were used to analyze data. First, demographic information were reported descriptively. Second, to answer research

objectives two and three, agri-food system understandings were analyzed using Hogan and Fisherkeller's (1996) strategy for representing highly complex student thinking about ecosystems. Lastly, strategies to ascertain general differences and comparisons were employed for research objectives four and five.

Analysis of Research Objectives Two and Three

Analysis of this data understandings involved four phases. First, I developed expert propositions related to the agri-food system and associated subconcepts. These were validated by MSU's Science Education and Agricultural and Extension Education faculty. Anderson (1995) suggests clinical interviews be limited in terms of the organization of academic knowledge, activities expected of students when they use that knowledge, and the schemata for communication needed when they use their knowledge. With this in mind, expert propositions and goal conceptions for fifth grade students and prospective elementary teachers (high school graduates) were based upon a synthesis of Benchmarks and the CALF (Trexler, 1997).

In the second phase, raw data from student interview tapes were analyzed by generating conceptual proposition maps. These maps served as summary portrayals of student thinking for each learning objective (West, Fenham, and Garrard, 1985). To assure accuracy of these maps, I viewed each videotape to translate student thinking into a concept map. Finally, maps were verified for accuracy by comparing them repeatedly to interview tapes of informants. At a minimum, each tape was viewed three times.

Phase three focused on coding student responses. The sophistication of student thinking about a given topic, as represented in the conceptual proposition map, was judged for each subconcept along two dimensions: quality (compatibility) and depth (elaboration of response) by comparison with expert propositions (Hogan and Fisherkeller, 1996). Student understandings were assigned codes based upon this comparison scheme (Table 12).

Table 12. Coding Scheme to Compare Propositions with Experts

Code	Description
CE (Compatible Elaborate)	Statement concurs with the expert proposition and has sufficient detail to show the thinking behind the concepts articulated.
CS (Compatible Sketchy)	Statement concurs with expert proposition, but lack essential details. Pieces of facts are articulated but are not synthesized into a coherent whole.
CI (Compatible/Incompatible)	Sketchy statements are made that concur with the proposition, but are not elaborated upon. At other times, statements contradict proposition.
IS (Incompatible Sketchy)	Statements disagree with the proposition, but provide few details, and are not recurring. Responses appear to be guesses.
IE (Incompatible Elaborate)	Statements disagree with proposition and students provide details or coherent, personal logic supporting them. Same or similar statements/explanations recur throughout the conversation.
N (Nonexistent)	Students respond "I don't know" or do not mention the topic when asked a question calling for its use.
ø (No evidence)	A topic is not directly addressed by a question and students does not mention it within the context of response to any question.

The final phase of analysis sought confirming and disconfirming evidence of patterns among individuals (Miles and Huberman, 1994). This was accomplished by two procedures. First, each subconcept was analyzed across individuals. And second, holistic portraits of student thinking were analyzed to ascertain how understanding or misunderstanding of subconcepts might influence understanding of another subconcept and ultimately, their understanding of the agri-food system. Examples of elementary student concept maps are provided in Appendix D. Elementary Concept Maps for Key Concepts II.B.2 and II.B.3. These maps graphically show how students differed in the understandings of two benchmarks pertaining to pests and crop protection.

Analysis of Research Objectives Four and Five

Research objective four sought commonalties among informants within groups with regard to background and experiences and their understandings of the agri-food system, while objective five sought differences that existed between the elementary student and prospective teacher informant groups.

To obtain a broad overview of the data for analysis in objective four (4), coding of benchmarks for each individual was tallied and placed on a grid. Next, I listed demographic background and experiences under each individual's tallied coding and looked for patterns. Once these were identified, I examined the specific nature of each coding in detail to determine commonalties relative to the understandings of individuals in both elementary student and prospective teacher groups.

For objective five, I utilized the same grids as for objective four. As in analysis of the previous objective, patterns were first identified. I did a side-by-side comparison of group codings for each benchmark, for example, I looked for the number of Compatible-Elaborate codes for a given benchmark X for the student group and compared this for the prospective teacher group. A difference between the group of at least of three (3) individuals in the Compatible-Elaborate group or three (3) in the Nonexistent group was used as a decision criterion. Once these differences were identified, I further examined the data to determine the specific differences in understanding that led to the discrepancy in the scores.

Summary

The ultimate goal of the methods used in this study was designed to describe what both elementary students and their prospective teachers understand about a complex system that is traditionally taught in a disconnected fashion. Gardner (1991) suggests that traditional quantitative methods of assessment can:

> provide clues to student understanding, [but] it is generally necessary to look more deeply if one desires firm evidence that understandings of significance have been obtained. For these purposes, . . . open-ended clinical interviews or careful observations, provide the best way of establishing the degree of understanding that students have obtained" (p. 145).

By employing the use of the clinical interview, idiosyncratic understandings were surfaced to answer questions about what knowledge people have and how they learn about technological concepts and systems. In the case of agri-food system technology, neither agricultural nor science educators have researched the understandings of elementary students or their prospective teachers.

IV. FINDINGS

Overview

This exploratory study was designed to determine elementary student and prospective elementary teachers' understandings of selective educational benchmarks for agri-food system literacy. To ascertain literacy and possible contributors to it, five (5) objectives were explored. First, the study probed background and experiences of the two informant groups to understand factors contributing to their understanding of the agri-food system. The second research objective sought elementary student understandings of five (5) clusters of educational benchmarks, while the third ascertained prospective elementary teacher understanding of these five (5) as well as two (2) additional clusters of benchmarks. The fourth objective sought commonalties in regard to understandings among individual members within the two groups. The final research objective targeted differences that existed between elementary teacher and prospective elementary teacher groups with regard to their understanding of the agri-food system educational benchmarks.

This chapter begins with the first research objective which is divided into its two components. Backgrounds of students are first explored, followed by those of prospective teachers. Next a summary/discussion section is presented that distills and comments upon salient points of the question. This same pattern is repeated for each section of all five research objectives. For example, in research objectives two (2) and three (3) multiple benchmarks are assessed and a summary/discussion section follows each benchmark. Research objectives four and five are not as detailed, so the summary/discussion sections for each aspect of the objective are included at the end.

Research Objective 1. Informants' backgrounds and experiences.

This section describes the demographic of elementary student and prospective teacher informants. Descriptions are first provided for the backgrounds of informants. After highlighting these attributes, food and agriculturally-related experiences are described for individuals in each of the two groups. The elementary student information is presented first, followed by that of the prospective teachers.

A. Background Demographics of Informants

In this section, informants were asked questions related to: 1) where they were raised, 2) the type of schools they attended, and 3) their parents' occupations. Along with these questions, visual characteristics were noted by the interviewer, e.g. gender and race.

1. Elementary students.

Found in Table 13 are specifics relative to student informant background including, gender, race, school, geographic location of where they were raised, parent occupation and socio-economic-status (SES).

Table 13. Elementary Student Background Data.

Name	Gender	Race	School	Raised	Parents' Occupation	Socio-Economic Status
Jay	Male	African American	Public School	Lansing	Father- Janitor Mother - State civil servant	lower middle class
Jill	Female	European American	Catholic School	Lansing	Father- State civil servant	lower middle class
Tom	Male	European American	Public School	Idaho, Oregon, and Lansing	Father- Science teacher	lower middle class
Jim	Male	African American	Lutheran School	Detroit	Mother- Word processor	lower class
Mona	Female	African American	Lutheran School	Detroit	Father- Airport porter Mother - pre-school teacher	lower class
Sara	Female	African American	Public and Lutheran School	Detroit	Stepfather- machinery repair Mother- shipping clerk	lower class
Tim	Male	European American	Public School	Suburb of Lansing	Father- Mental health administrator	upper middle class

					Mother-Secretary	
Ema	Female	European American	Public School	Suburb of Lansing	Father-Pharmacist Mother- Pre-school teacher	upper middle class
Liz	Female	European American	Public School	Suburb of Lansing	Father- Engine designer Mother-Teachers' aide	upper middle class

The following is discussion of data found in Table 13. Four (4) of the nine (9) informants were male. The racial background of the elementary student informants was split between those from European and African ancestry: five (5) were European American and four (4) were African American. All but Tom were raised exclusively in Michigan. He had lived previously in rural Idaho, Montana and Oregon. Five (5) informants grew up in urban areas, three in the city of Detroit (Mona, Jim, and Sara) and two in Lansing (Jill and Jay). The remaining three informants said they grew up in the suburbs of Lansing (Tim, Ema, and Liz).

Students attended two types of schools: parochial and public. Jill, Jim, Mona and Sara attended religiously-based schools. Only Sara had attended both public and parochial schools. The remaining five (5) students attended Michigan public schools.

Elementary informants were selected specifically based upon the socio-economic status (SES) of their parents. Of the nine (9), Mona, Jim, and Sara were labeled as lower SES because they were eligible for the Federal Free and Reduced Lunch program; three (3) were considered lower middle class (Jay, Jill and Tom) as their parents made less than $50,000 per year. The final three (3) informants (Tim, Ema, and Liz) were classified as upper middle class because their family incomes exceeded $85,000 per year.

Obviously, parental employment determines SES level. Students were asked the occupations of their parents. Jay lived with his mother who worked as a civil servant in state government. His father lived a few blocks away, and he was employed as a janitor and cook. Jill's father was also employed in state government in the social services department. Tom's father was a science teacher in a suburban middle school.

As expected, the students' parents from Detroit--selected as representatives of lower SES-- held jobs that required less education. Jim's mother worked as a word processor, while his grandmother stayed at home. Mona's father was a porter at the Detroit Metro Airport, and her mother worked as a shipping clerk. Sara lived with her stepfather and mother, he a mechanic and she a secretary.

The students from the highest SES all lived with both parents, and each of the parents worked outside the home. Tim's father was an administrator for a mental health company and his mother was a secretary. Ema's father was a pharmacist, while her mother worked as a pre-school teacher. Finally, Liz's father was an engine designer and her mother a teacher's aide.

2. Prospective teachers backgrounds.

Table 14 provides background information for the prospective teacher informants. The same information is provided as was for the elementary student informants.

Table 14. Background of Prospective Teacher Informants

Name	Gender	Ethnicity	School	Raised	Parents' Occupation
Sid	Male	European American	Public School MSU, El Ed, Social studies	Suburban Detroit	Father- Electrician
Kat	Female	European American	Public School MSU- El Ed, English	Suburban Detroit	Mother- High School Science teacher Father- Landscape architect
Molli	Female	European American	Catholic School MSU- El Ed, Special Education	Detroit	Mother- Pre-school teacher Father- Special Education teacher
Kara	Female	European American	Catholic School MSU- El Ed, English	Southern Rural Michigan	Father- Farmer
Di	Female	European American	Public School MSU- El Ed, English	Detroit	Father- Detroit Civil Servant
Dan	Male	European American	Public School MSU- El Ed, Agriscience	Southwestern Rural Michigan	Father- Hardware store owner
Guy	Male	European American	Public School MSU- El Ed, Social studies	Suburban Detroit	Father- Janitor Mother- Sales clerk
Meri	Female	European American	Public School MSU- El Ed, Social studies	Southeastern Rural Michigan	Mother- Real Estate Agent

Three of the eight informants were male. All prospective teacher informants were European American. They were all raised in Michigan, although in different the locations. Three (3) informants grew up in areas that they described as rural (Kara, Dan and Meri), while, on the other extreme, two (2) said they grew up in the city of Detroit (Molli and Di). The remaining three (3) informants grew up in the Detroit suburbs (Sid, Kat and Guy).

Differences were also noted in the types of schools that they attended before college: two (Molli and Kara) had attended Catholic schools only, while the remainder had exclusively attended public schools. All students attended Michigan State University, were elementary education majors and were either Juniors or Seniors. They did differ, however, in their areas of concentration. Three of the prospective teachers focused on social studies (Sid, Guy, and Meri) and three (Kat, Kara, and Di) minored in English. The two remaining informants had special education and agriscience degrees as minors (Molli and Dan, respectively).

The occupations of the informants' parents varied greatly. Sid's father was a skilled electrician. Kat stated that her mother was a high school science teacher and her father was a landscape architect; they were divorced. Molli's parents were both teachers: her mother of pre-school children and her father of children with special needs. Interestingly, Kara said that her father was a full time cash-crop farmer. On the other extreme, Di's father worked within the bureaucracy of the city of Detroit as a civil servant. Dan's father owned and operated a hardware store in a small rural community, while Guy's father was a janitor for a suburban school district and his mother worked at a record store. Meri's mother sold real estate in a rural southeastern community of Michigan.

Summary/Discussion

There were nine (9) elementary students in this study: five (5) were female and four (4) were male. They were of European or African ancestry and came from urban and suburban locations. Four (4) of the student informants attended parochial school, and the remainder were in public schools. The parental occupations ran the gamut from janitor to pharmacist. The informants were evenly divided by soci-economic status (SES) groups: lower, lower-middle, and upper-middle.

One of the students who lived in a urban location had once lived in rural areas in western states. The other informants had only lived in the locations where they were interviewed. The fact that one student lived in various places while growing up is of some import to this study. He cannot be compared with the other urban students for purposes of generalizations.

The prospective teacher backgrounds were less varied than the student informants. There were eight (8) informants in this category; three (3) were male and five (5) were female. All of them were of European ancestry-- all were white. They did vary in their schooling. Two (2) had attended Catholic school, and the remaining (7) attended public school before college. All informants attended MSU and majored in elementary education, although they had different minors. Although they were not purposefully selected for variance in geographic locations where they were raised, three (3) students came from rural backgrounds, three (3) from the suburbs and two (2) from the city of Detroit. Just as with the elementary student informants, occupations of the prospective teachers' parents varied--from janitor to landscape architect.

Although the prospective teacher informants are less varied than the other group, they is representative of most of MSU's teacher education students. There is, however, a greater percentage of males in this prospective teacher group than is typical for elementary education. This fact, I believed at the beginning of this study, might bias the results. In the end, though, I was proven wrong. Gender was not play a factor in understanding the agri-food system. On the other hand, over thirty percent (30%) of the informants came from rural backgrounds. This provided an interesting contrast to the urban informants that is discussed later in this study. Also notable is that one prospective teacher informants father was a farmer. On the whole, then, this group may have been slanted toward a more rural orientation than most prospective elementary teachers from Michigan State University.

B. Food and Agriculturally-Related Experiences

Along with gathering demographic information that described elementary and prospective teacher informants, questions were asked that focused on food and agriculturally-related experiences. These questions were designed to determine in what experiences informants had engaged relative to gardening and the purchase and preparation

of food. Again, as with the previous section on background, elementary students are described first, followed by prospective teachers.

1. Elementary students.

Table 15 summarizes experiences of elementary students.

Table 15. Food and Agriculturally-Related Experiences of Elementary Student Informants

Name	Shopping	Cooking	Gardening	Farming
Jay	Yes , mother	Sometimes cooks steak.	Yes, with mother.	No
Jill	Yes, mother	Doesn't cook.	No	No
Tom	Yes, mother	Sometimes macaroni and cheese	Yes, with father.	No
Jim	Yes, mother	Mixes things for grandma.	Yes, with grandma.	No
Mona	Yes, mother	Cooks cookies with mom and had cooking class.	Tried to grow plants, they died. No vegetables.	No
Sara	Yes, mother	Helps mother sometimes.	No	No
Tim	Yes, mother	Cooks with canned food.	Yes, with grandma.	No
Ema	Yes, mother	Cooks macaroni.	No	No
Liz	Yes, mother	Cooks cookies, never meals.	Yes, with mother	No

No student had ever worked on a farm at any time in his/her life. Along the same line, only three (3) students (Jill, Sara, and Ema) had ever helped grow a garden. Mona said that she had planted flowers in the past, but they had died. She had never grown vegetables. The remaining elementary informants had all been involved in growing a garden in some way. Jay, Tom, and Liz had grown gardens with their parents, while Jim and Tim had experienced gardening with their grandmothers.

Students were asked their experiences relative to purchasing and preparing food. All informants stated that they had gone grocery shopping with their mothers at some point in their lives. On the one hand, their experiences with cooking food varied. Only Jill had never cooked. All others said they occasionally either helped a parent or grandparent in the kitchen or prepared simple items such as macaroni and cheese, steak or cookies. It is noteworthy that only Mona had taken a cooking class in school.

2. Prospective teachers.

Table 16 identifies food and agriculturally-related experiences of prospective teachers.

Table 16. Food and Agriculturally-Related Experiences of Prospective Teacher Informants

Name	Shopping	Cooking	Gardening	Farming
Sid	Yes , mother	Sometimes cooks	Yes	No
Kat	Yes, mother	Doesn't cook	Yes, with father when young	No
Molli	Yes, mother	Now just beginning to cook	No	No
Kara	Yes, mother	very little cooking	Yes	Sometimes with father
Di	Yes, mother	One day a week when young, now all daily	No, but Grandparents did	No

Dan	Yes, mother	Yes, pasta anything quick	Yes	A little with friends
Guy	Yes, mother	Cooks every night	No	No
Meri	Yes, mother	Loves to cook	Yes	No

As noted in Table 16, only Kara and Dan had experiences working on farms. Kara, when young, worked with her father on his cash-crop farm. She also described how her family always raised their own beef cattle for meat. Similarly, Dan stated that he had helped out at neighbors' farms when young and that he currently had friends who owned large farms he visited regularly.

In a similar vein, five (5) informants (Sid, Kat, Kara, Dan, and Meri) had home gardens when they were young. Di stated that she did not have a garden at home, but that her grandparents had one. Only Molli and Guy reported that they did not have a garden while they were growing up. This is contrasted by the fact that all informants had gone to grocery stores with their mothers to shop for food at some point in their lives.

The final area addressed in the interview was food preparation. Informants were divided into two categories with regard to cooking–those who cooked every night and those who cooked seldom or never. Guy and Meri said that they enjoyed cooking very much and did so every night for dinner, while the other informants fell into the category of seldom to never cooking.

Summary/Discussion for Food-based Experiences

All elementary students had shopped with their mothers for food. Most had helped out in the kitchen, but they did not play a major role in food preparation. Only one (1) elementary student had had a cooking class in school. Relative to gardening, only two (2) students had never been involved in growing food. No elementary student informant had ever worked on a farm, but one (1) had lived in areas near farms.

As with the previous group, all prospective teacher informants had shopped with their mothers for food. They ranged in their experiences with cooking from never cooking to an impassioned love of cooking. For the most part, though, most prospective teachers occasionally cooked for themselves. As for gardening, five (5) informants had grown food with their parents, one (1) young woman's grandparents had a garden, while two (2) had no experience whatsoever. Interestingly, two (2) informants in this category had experiences working on farms.

All informants had food-based experiences. The primary difference among them was experience with gardening. Two (2) informants in each group had never grown food. Of these, three (3) were raised in Detroit and the other in one of its suburbs.

Research Objective 2. Elementary students' understandings of the agri-food system goal conceptions.

Research objective two (2) was addressed by analysis of elementary student informant's discourse generated during interviews. Specifically, students were prompted

to respond to questions aligned with the agri-food system literacy benchmarks found in Table 1. Analysis is based upon five (5) clusters of benchmarks that correspond to key concepts that are formulated into questions. A total of thirteen (13) benchmarks were assessed in the elementary student informant section. Student responses were coded by comparing discourse compatibility and extensiveness with the expert conceptions for each benchmarks. These are found in Figure 1.

Elementary Benchmarks and Sub-components

The analysis of elementary students begins with four (4) benchmarks related to a general understanding of: the Agri-food system, moves onto a detailed look at eight (8) Science: Agricultural-Environmental Interdependence oriented items, and concludes with one (1) Cultural-Historical benchmark detailing technological affects on society.

I. Agri-food System

A. Concept of Agriculture

Table 17 lists codings of elementary informants' understandings of a key concept from section I. Agri-food System, What is agriculture? Four (4) benchmarks necessary to answer the key concepts are found in the table. Analysis of the benchmarks follows.

Table 17. Elementary Student Understanding of: I.A. What Is Agriculture?

Benchmarks	Jay	Jill	Tom	Jim	Mona	Sara	Tim	Ema	Liz
1) Identify food and fiber products that come from plants and animals.	CE	CE	CE	CE	CE	CE	CE	CE	CE
2) Describe the variety of farms and their products.	CS	CS	CE	CS	CS	CS	CE	CS	CE
3) Describe the journey of a food or fiber product as it travels from the farm to the consumer.	CE	CE	CE	CE	CE	CE	CE	CE	CE
4) Describe how agriculture uses natural resources to provide peoples' basic needs.	CS	CS	CS	CS	CE	CE	CS	CE	CS

ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy; CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate

1. Food and fiber products come from plants and animals.

As indicated in table 17, all elementary students were Compatible-Elaborate in explaining their understanding of the expert conception. They explained that the lettuce came from a plant and that meat came from an animal. Jill and Mona, however, did not know from what animal the meat came.

2. Variety of farms and their products.

Tom, Tim, and Liz were coded as Compatible-Elaborate. They stated that lettuce could come from either a farm or a garden. Gardens were considered to be smaller and included diverse crops, while the lettuce on the cheeseburger probably, they all said, came from a large farm that grew few crops (specialization). Tom's comments to interview questions pointed out the distinction, found in the Compatible-Elaborate responses, between farm and garden:

Interviewer- Where do you think the lettuce came from that is on this burger?

Tom- From maybe a field of it. Or maybe a kind of like an orchard.

I- Tell me about the field. What does it look like?

T- Probably, not probably, middle size, middle size field, like rows.

I- Ok, people usually think of acres maybe like a football field size. So how many, um, one half of the football, one full, several football fields, how big?

T- Probably half a football field.

I- Ok, and then what was that, what does the plant look like? How are there, you started talking about rows.

T- Like it would, it would be like rows, yeah or pretty much rows with it. So the sprinklers can lay there too.

I- Ok. I know what you're talking about, but those kind of metal pipes.

T- Yeah. Probably like this far apart and it goes down on the ground like that. It's like up on a hill.

I- Right where the lettuce is.

T- Yeah.

I- Ok. Now was anything else growing near the lettuce?

T- No, just lettuce.

I- Just lettuce? Ok.

T- Except for it came from a garden that has lots of . . .

I- But where do you think this, this lettuce came from?

T- This, probably from a field that has all lettuce.

On the other hand, the remaining informants were coded Compatible-Sketchy as they described a farm as being like a large garden that grew various crops in alternating rows. It is noteworthy that even though Tom, Tim and Liz said farms were large, the largest farm described by any informant was four (4) football fields in size. Of further interest is that Liz never used the word farm in her interview, but instead used plantation.

3. Journey of a food or fiber product as it travels from the farm to the consumer.

All elementary students were coded Compatible-Elaborate in their understanding of lettuce's journey from farm to consumer (Table 17). They understood that lettuce was produced on farms and was shipped via trucks to restaurants for consumption. Only Liz said that lettuce was shipped directly from a plantation (which had a factory behind the fields that removed bugs from the lettuce) to the McDonald's restaurants. All other informants said that the lettuce was sent via truck to some type of a factory for cleaning. From there, everyone but Sara said that it was transported by truck to the restaurants. Sara believed that it was sent to a grocery store and that the manager of the restaurant purchased it as needed. It is noteworthy that only Mona and Liz believed that the lettuce could be shredded and placed into bags prior to shipment. Mona also stated that the factory where the lettuce was cleaned was the "head" McDonalds.

Tim describes his version of the journey that lettuce travels:

I- Tell me about the process to get from the farm to a McDonalds.

T- Well, they probably have a big trucks that are like, like working for the company that drive down there . . .

I- What company?

T- Any company like, a company who just does like plants, who makes plants, like plants, like vegetables. Probably package em, wrap em up, so a company is made . . .

I- Ok. So they got this company. Where does it wrap that up at?

T- It probably goes in this machine.

I- Where is the machine?

T- Probably in the factory.

I- How does it get to the factory?

T- Well probably have heads of lettuce are put up in a truck or something, bring it to the factory where it gets washed and like kill the germs, bring them to this machine in the factory. The factory where they package the plants and send them to the truck.

I- And then this truck . . .

T- The truck drives down to Michigan and gives them to McDonalds.

I- So McDonalds gets the head of lettuce.

T- Probably there are McDonalds companies down there.

I- Who buys it?

T- McDonalds.

Liz provides a similar but more elaborate description of the journey:

I- Let's focus in on the lettuce. Can you tell me, how did that, you can do this one of two ways. Either think about it being at McDonalds and go backwards and tell me where did it come from originally or, if it makes more sense to you, go the other way.

L- OK, well I guess it starts like a seed. And it grows into a big head of cabbage, or lettuce--whatever you call it. And then they like put it into a factory and like make sure all the bugs and stuff are out of it. And ship it to, like, and they use the food like at McDonalds.

I- OK, what was the place where the seeds grew, where they planted them?

L- I don't know.

I- What would you call the place?

L- Um, a plantation.

I- OK, and then where do you think that plantation was?

L- I don't know.

I- So tell me then, how did it get from the plantation; where did you say it went next?

L- Um, they ship it.

I- OK, how was it shipped? [overlapping speech]

L- Or, well they don't like ship. Well like some of the truck drivers sometimes they usually, um like, bring it to the place. Like if you have a can of Coke™, then they carry it into the trucks, like [to] the schools and fill the machines with it. Well it's like, lettuce comes in the truck and they bring it like to McDonalds or Wendys.

I- OK, but you said something about a factory before.

L- Oh, well I meant plantation.

I- OK, can you tell me how it, tell me the steps, where it goes to get to McDonalds. What are the, it goes from the plantation to where?

L- Well the trucks are, they load the lettuce into the trucks and they bring it to like McDonalds. I don't know.

I- Last time you talked about a factory and bugs.

L- I guess that they take, like make sure there's like, no diseases in it or bugs. Like clear that all out. Because it's sort of like, you know with the cows, they have machines that, um, make it so you can drink it. But the lettuce, like they take all the bugs out of it and make sure it's good to eat. So it's not like bad, so you don't get sick or anything. And then they probably wrap it up, like so you can buy it and put it into the truck and take it to McDonalds or the to stores.

I- So when it gets to McDonalds, what does it look like?

L- Like they may cut it up like that [pointing at the cheeseburger]

I- At McDonalds, at the restaurant?

L- Ya, or you can buy it, or they may cut it up at the thing, into little pieces like that or you can get the big.

I- What's the thing?

L- Cut it up at the plantation.

I- At the plantation, OK.

L- Or the factory.

4. Agriculture uses natural resources to provide peoples' basic needs.

Table 17 indicates that Ema, Mona and Sara were coded Compatible-Elaborate for their understanding of the need for natural resources for crop growth. They stated that plants needed water, sun, air and soil for growth, while their contemporaries were Compatible-Sketchy because they neglected to discuss the requirement for air (carbon-dioxide and oxygen).

Summary/Discussion

Elementary students had no trouble explaining that plants and animals were the source of foods, in this case lettuce and meat.

They all--except one who said plantation--knew that food grew on farms. The majority, however, believed that farms looked like large gardens where each row contained separate crops. Three students spoke of specialized farms where lettuce would have been the only crop grown. They distinguished these from gardens which were smaller and more diverse. Students were unaware of the actual size of modern farms--the largest described by any informant was four (4) football fields. This is an area of interest as most farms producing lettuce exceed a hundred acres.

Informants were able to discuss the journey lettuce traveled from farm to consumer at a fast food restaurant. They understood that it was harvested, transported, processed, and delivered to restaurants. One (1) student believed that the restaurant manager purchased the lettuce at a grocery store. The majority, though, said that it was delivered to the restaurants. My impression is that many of the informants were reasoning out the journey of lettuce as they spoke--many seemed to have never considered it before. All did, however, come to a plausible story for the journey. Educationally speaking, it is interesting to note that students drew upon examples they were familiar with (e.g., Coke™ delivery at their school) to explain the system that brought them food.

The final benchmark under this Key Concept dealt with natural resources necessary for agriculture to meet the basic needs of people. Three (3) informants accurately described natural resources necessary for plants and animals to grow. They spoke of air as a natural resource, while their contemporaries only mentioned sun, water, and soil for plants and water and food for animals. The plant growth requirements are examined in detail in benchmark II.B.1. As to be expected, based upon studies by science educators cited in the literature review, students simply parroted back the names of natural resources and did not have a deep understanding of what they did for plants and animals.

II. Science: Agricultural-Environmental Interdependence

The Science: Agricultural-Environmental Interdependence section examines three (3) key concepts and eight (8) benchmarks corresponding to the concepts. The key concepts include: A. Ecosystem Management, B. Crop Management to Promote Growth, and C. Role of Science and Technology in the Agri-food System.

A. Ecosystem Management

The first key concept deals with human management of ecosystems and its benchmark focuses on how crops grown by humans depend upon climate and soil. Student codes for understanding of this benchmark are displayed in Table 18.

Table 18 Elementary Student Understanding of: II.A. How Are Parts of the Ecosystem Managed by Humans, and How Do They Interact?

Benchmarks	Jay	Jill	Tom	Jim	Mon	Sara	Ti	Ema	Liz
1) Describe how crops depend on an area's a) climate and	N	CS	CE	CE	CS	CS	CE	CE	CE
b) soil for growth.	IS	CS	CS	CS	CS	CS	CS	CS	CS

ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy; CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate

1. Crops depend on climate and soil.

a. Climate

Tom, Jim, Tim, Ema, and Liz were Compatible-Elaborate in their description of how crops depend on climate for growth (Table 18). Their descriptions included elaboration on the impact of rainfall and temperature on crop growth, while Jill, Mona, and Sara were Compatible-Sketchy because they did not directly allude to rainfall or other forms of precipitation. Jay's understanding of climate's impact on plant growth was Nonexistent. Although he provided the response "water" previously in benchmark 1.A.4., he did not connect plant growth needs with climate.

b. Soil

All informants--except Jay--were Compatible-Sketchy for their understanding of soil's role in plant growth. Jay explained that soil was food for plants and was coded Incompatible-Sketchy. No informant listed all three functions of soil as found in the expert conception. They did not mention that soil provided plants with minerals needed for plant growth--a foundational concept of crop production.

All informants knew that soil was needed for plant growth, but they could not articulate deep and elaborate reasons why it was needed. Sara, Ema and Liz mentioned that soil was needed for roots to grow and stretch out. Tom and Liz said that soil had to be "good." Tom could not explain what made it "good," while Liz said that good soil had few rocks and weeds. Ema said that roots got the water from the soil. Sara's response is typical of her contemporaries:

I- Ok. And then what else does it need? Did you say, what else did you say it needs?

S- Probably it needs soil.

I- Ok, why?

S- So that the roots can grow.

I- Ok. Does it . . . does it get anything from the soil?

S- Probably fertile soil. I don't know.

I- What does it mean? What is fertile?

S- Rich soil or something.

I- Rich in what?

S- [three second pause]

I- Fertile with what?

S- [four second pause, on to the next prompt]

Summary/Discussion

A majority of informants, five (5), understood that plants need specific climate for growth and said that climate included temperature and rainfall, while the remainder mentioned temperature, but not precipitation. Overall the understanding of climate's role was fairly well developed, with the exception of one informant. Rather than misconceptions about climate, students that were not coded as CE held "non-conceptions."

Soil was a topic where all students had incomplete understandings. Most knew soil did something and it had to be good, but they did not say what made it good. One student offered a statement that it had to be rich and fertile, but she was unable to support this proposition.

The murkiness of understanding of soil's role in crop production is noteworthy. The idea that plants acquire minerals from soil and that these are essential for growth undergirds an understanding of why fertilizers are used and why they are beneficial to crop production. It is evident that this group of elementary informants does not have the requisite understanding that is foundational to a deeper understanding of crop growth and management. The topic of soil is addressed in further detail in benchmark II.B.1.

B. Crop Management to Promote Growth

The second key concept under the rubric of Science: Agricultural and Environmental Interdependence involves the management of crops to promote growth. There are four (4) benchmarks found in Table 19. They cover the requirements for plant growth, crop protection, pest management, and the impacts of using poisons (pesticides) to protect crops.

Table 19. Elementary Student Understanding of: II.B. How do humans manage crops to promote growth?

Benchmarks	Jay	Jill	Tom	Jim	Mona	Sara	Tim	Ema	Liz
1) Describe basic growth requirements for plants and animals.	CS	CS	CS	CS	CS	CS	CS	CE	CS
2) Describe how crops may be lost to pests.	CS	CS	CS	CS	N	N	CS	CE	CS
3) Explain how crops are									

protected from weeds and pests.	CS	CS	CS	CS	N	N	CS	CS	CS
4) Describe the positive and negative impacts of using poisons to protect crops.	N	N	CS	CS	N	N	N	CS	CS

ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy; CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate

1. Basic growth requirements for plants and animals.

All elementary students, except Ema, were coded Compatible-Sketchy for their understanding of the basic growth requirements of plants and animals (Table 19). Although they knew bits and pieces of the requirements (See benchmark A.1.4- natural resources), they did not integrate this into a compatible and elaborate understanding. New ideas that surfaced as a result of this prompt were proffered by Mona, Jim, and Sara. They stated that air or atmosphere or CO_2 was needed for plants to grow, but they didn't know why.

Only Ema offered a Compatible-Elaborate description of the growth requirements for crops. She added to benchmark 1A.4. by stating that air was needed by plants to make food and that space was required. She went on to say that weeds could compete with plants for space which could limit the amount of sun that crops received. She said sun was also needed by plants to make food.

All informants said that animals (the cattle that made the meat) need food and water to live. Only Ema and Tom included the idea of protection from extremes of temperature, while Ema also included the need for air and space. Ema's canonical knowledge of growth requirements was elaborate for an elementary student.

2. Crops may be lost to pests.

In benchmark 2 "Describe how crops may be lost to pests" informants were coded into three (3) classifications: Compatible-Elaborate, Compatible-Sketchy, and Nonexistent (Table 19). Only Ema was Compatible-Elaborate in her description of the two parts to this benchmark--weeds and animal pests. Jay, Jill, Tom, Jim, and Tim were Compatible-Sketchy; and Mona and Sara were Nonexistent. Ema, Liz and Tim said crops needed to be protected from weeds. Tim explained in detail about how dandelions "stole" water from trees, while Liz' response to why weeds were removed from her home garden was based only on them being "tacky." She lacks an understanding of how crops are lost to pests. Liz describes her home garden:

L- Um, if it has rocks and stuff in it, like in the dirt, and in it, or weeds or something. Like in our garden, we always pick out the weeds and like old roots and stuff.

I- Can you tell me, why do you think you pick out the weeds in your garden?

L- So then, they don't grow bigger and, I don't know, so it looks better.

I- OK, what would be wrong if they grew bigger?

L- The garden would look really tacky.

I- OK, so it has to do with looks.

L- Ya, and um, because weeds aren't the best things to have, because they like, I don't know. We usually pick them out in our garden because they'll look bad.

Even though Tim and Liz held a much more developed schema relative to crop loss to weed pests, they did not have a Compatible-Elaborate understanding of the goal conception and were coded Compatible-Sketchy. Interestingly, their contemporaries did not mention weeds at all during the interview.

Relative to animals as pests to human crops, only Ema and Liz stated that these pests could be both rodents and insects. Jay, Jill, and Tim spoke only of rodents and Tom and Jim only of insects. Additionally, Tom, Jim, Ema, and Liz knew that these animals could affect crops by eating and nesting in them, while Jay, Jill and Tim only mentioned animals eating plants--this may be logical as they viewed animals affecting plants as large. Interestingly, no informant mentioned birds as pests to crops.

Neither Mona nor Sara spoke of pests at any time during the interview.

3. Crops are protected from weeds and pests.

All informants--with exception of Mona and Sara--were coded Compatible-Sketchy. Mona and Sara did not mention pests in benchmark II.B.2. Therefore they did not have the requisite background to understand that crops needed to be protected from pests--they were coded Nonexistent. In the expert conception for this benchmark, three

(3) methods were listed to protect crops: 1) establishing of barriers to animals, 2) killing of pests with poisons (pesticides), and 3) breaking the life cycle of pests through management techniques. No informant spoke of all three methods, but one--Tim--added the use of scarecrows and decoy snakes, which seemed plausible.

Elementary student understanding of this benchmark was dependent upon their knowledge of pests. Because Tim, Ema and Liz knew that weeds could be a problem to growing crops, they all discussed the need for their removal. However, they did not mention using chemical compounds--herbicides--to rid gardens and fields of these pests. Other explanations of how crops are protected from pests were equally based upon student past understanding of what pests were. For example, Tim, Ema and Liz stated that animal pests could be both rodents and insects, while Jay and Jill only mentioned rodents. Both groups stated that fences could be used to prevent pests from plaguing crops. On the other hand, Tom and Jim, because they viewed pests exclusively as insects, stated that sprays (pesticides) could be used to protect crops by killing bugs.

The notion of using a spray to fend off insects was also shared by Tim, Ema and Liz--they stated that insects were pests to crops.

Ema explained crops were protected by pesticides:

I- Is there anything that the person who is growing this might need to protect the lettuce from?

E- Um, bugs . . .

I- Tell me about that.

E- Um, the bugs, there are certain bugs that like lettuce and vegetables and things and other things like rabbits that like to eat them. And they might have to put up like cage or something around them to help them.

I- Can you tell me about the bugs? How would then, what would they do?

E- They eat the lettuce. They, I am not sure, they eat the lettuce.

I- Ok, um, with these bugs eating the lettuce. Is there anything that the farmer might do or the person who is growing has to be able to protect the lettuce?

E- Yeah, they could um spray the lettuce.

I- With what?

E- With like bug spray or something.

I- What does that do?

E- It keeps bugs away from, . . . it kills the bugs.

Liz believed that "sprays" are like repellents that she has used for insects:

I- Anything else that they might protect the lettuce from?

L- Could put like spray stuff on it so like the rabbits, like I don't know, if they have any stuff for it. But I know like, um, we put stuff on it, like for bugs, you can put stuff on it, like for us we put, like OFF™ or something on us, so the bugs don't bite us, so you can

I- Oh, you spray stuff on plants for bugs, not rabbits?

L- I don't know, both?

I- Both.

L- Ya,, we usually, for our, like we don't have any rabbit stuff, but you can use it for mostly bugs.

No informant mentioned the use of management techniques such as crop rotation or pasture rotation as a means by which pests could be controlled. It is noteworthy that Jay, when asked about what cattle needed to be protected from, explained that cattle needed to be protected from: 1) people with guns and 2) kids running cattle into fences.

4. Positive and negative impacts of using poisons to protect crops.

The expert conception for the benchmark describing the positive and negative impacts of using poisons (pesticides) to protect crops was very complex. On the positive side of using pesticides (poisons) was the: 1) reduction of time and labor, 2) increase in crop yield and its resultant decrease in price of food, and 3) decrease in human disease capsized by pests. Conversely, negative impacts included the: 1) expense of purchasing and using pesticides, 2) contamination of the environment resulting in morbidity and mortality to living things, 3) resistance to pesticides by pests and resulting in dependence on products that no longer serve their purpose, and 4) the move away from sustainable practices because of a reliance on "quick fixes" such as pesticides. No informant included more than one positive or negative impact of pesticides. In fact the majority (Jay, Jill, Mona, Sara, and Tim) was coded Nonexistent for this benchmark. The remaining Compatible-Sketchy informants (Tom, Jim, Ema, and Liz) all stated that

pesticides would help plants by preventing their destruction, thereby leading to an increased yield. Thomas also mentioned that this would increase profits for the farmer. On the negative side, Tom, Jim and Liz mentioned that pesticides could result in contamination of foods. Liz explained that people might be allergic and plants might not tolerate the material:

I- OK, so let me asked you something about that. So if you sprayed this stuff, you said like OFF™ right?

L- Ya. [overlapping speech]

I- Like we spray ourselves. If you sprayed that on plants, so the good thing about it is that it keeps the bugs off. Are there any bad things about it?

L- Um, I don't know, some people may be allergic to it. Maybe if the plants can't take it, they'll die, like if they can't [take] the stuff that you spray on it.

Jim said that people would have to wash their produce and Tom commented that a disadvantage would be harm to plants as well as to humans. Tom's comments are strikingly similar to Liz':

I- You talked about, using those things that protect the plants from like bugs. Can you think of, so what's good about that?

T- Well, it kills the bugs and some of the bugs won't eat the plant. Bugs eat plants.

I- Ok. Anything that disadvantage to that?

T- It could harm the plants, say they put too much on it and the people grind it and eat it. It might harm the person who eat it. If it's too much on it.

I- Do you ever think about that? Do you have . . .

T- Yeah. Sometimes. If it's like on fruit, because they do spray on fruit. And then you always have to wash it off before you eat it, 'cuz it could have, it's, it's poisonous to you probably. And it's poisonous to bugs.

I- Ok. Um, so do you always wash off your fruit?

T- Yeah. Strawberries and apples, something like that.

It is noteworthy that no informant used the term pesticide at anytime during the interviews. Bug spray and sprays were the terms most commonly used. Additionally, Liz and Jim used the analogy of OFF™, a repellent to discuss these substances--they didn't mention the killing of these insects.

Summary/Discussion

The cluster of benchmarks under the key concept of crop management to promote growth were not well understood by most informants. In the first benchmark related to basic growth requirements for plants and animals, eight (8) of the (9) informants did not articulate a clear understanding. Only one (1) student described all plant growth requirements. The remainder did not mention space as a requirement for growth and only two (2) of the eight (8) spoke of air. The one (1) student who talked about both air and space articulated a clear understanding of the sun's role in the production of food for plants and mentioned air as helping to produce food. As mentioned in benchmark I.A.4 and II.A.1, students parroted back memorized knowledge about plant and animal growth requirements but had little understanding of what role they played in plant growth and sustenance. This finding has been supported by science researchers for the past two decades.

The one (1) female student mentioned above consistently demonstrated the highest level of canonical knowledge of traditional science concepts. She spoke of how weed pests compete with crops for sun, space and minerals from the soil. Only one (1) other student spoke at length about competition from weeds and only one (1) other, for a total of three (3), mentioned weeds at all. Only three (3) informants spoke of insects and rodents as pests, the other four (4) who talked of pests mentioned either rodents or insects, not both. Two (2) informants did not speak of pests at all. This lack of or nonconception limited understanding of how one might protect crops from pests.

Protecting crops with poisons (pesticides) was mentioned by only those who spoke of insects. Those who talked exclusively about animals (insects not included) did not consider the "spraying" of plants. Of equal, maybe even greater, import is that the majority did not mention pesticides as a way to protect plants and animals at all. In fact the word pesticide was never mentioned by any informant. Without knowledge of pests and how humans control them, there is no way to intelligently weigh the positive and negative affects of using pesticides. As such, this could be a reason why people are willing to spray insect repellent on themselves for mosquitoes, but are frightened of pesticide residue on their food.

C. Role of Science and Technology in the Agri-food System

The next Science: Agricultural-Environmental Interdependence related key question deals with understanding the role of science and technology in the agri-food system. There are three (3) benchmarks that are foundational to developing knowledge and understanding to address the aforementioned question. Table 20 lists the elementary student informant codes for these benchmarks.

Table 20. Elementary Student Understanding of: II.C. What is the role of science and technology in the agri-food system?

Benchmark	Jay	Jill	Tom	Jim	Mona	Sar	Tim	Em	Liz
1) Explain why a) *irrigation* and	CS	CS	CE	CS	CS	CS	CS	CS	CS
b) fertilizers are used to grow crops.	CS	N	N	N	N	N	N	N	CS
2) Identify the places of origin of common foods eaten by Americans: lettuce	N	N	CE	CE	N	N	CE	CE	CS
beef	CS	CS	CE	CE	N	N	CE	CE	CE
3) Describe how places too cold or too dry to grow certain crops can obtain food from places with more suitable climates.	CE	CE	CE	CE	CE	CE	CE	CE	CE

ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy; CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate

1. Irrigation and fertilizers.

a. Irrigation

Only Tom held Compatible-Elaborate understanding of why irrigation was used to grow crops. His answer included acknowledgment that: 1) a constant supply of water is necessary for crops to grow, and 2) humans grow crops in places that are unsuitable for crops to grow. He discussed how in Idaho there were machines (center pivot irrigation systems) that watered the crops because it never rained enough. His contemporaries all stated that plants were watered because plants needed it, but neglected to mention that humans grew crops in areas were they often times did not get much rain; they were all coded Compatible-Sketchy. It is noteworthy that no student used the word irrigation in their discourse about this topic.

Sara, one of the students who was labeled Compatible-Sketchy, had no idea of water's origin that might be given to crops. In fact she speculated men and women rode chariots to deliver water in glass bottles. When asked if this was in the past or present, she said in the past (although my impression was/is that she believed it to be the case today). When asked about the origin of water today, her frame of reference was obviously an urban one. Sara states:

I- Anything, any ideas about it? With, is there anything . . .

S- Make sure they get water.

I- Ok. And what would happen if they were not getting water?

S- They will probably die, 'cuz they need the water to survive.

I- Is there any way that the farmer can get the water to the plant?

S- Probably if they, um, they probably use a hose to spray the water.

I- Do you think they ever do that?

S- No.

I- Ok. What you are saying is that they plant the seeds. If it rains, great. If it doesn't, then they might lose everything that they planted.

S- Yeah, sometimes rain can help the plants, if it rains enough.

I- Well, how does it get water if it didn't rain.

S- Um, people have to do it by themselves. They, if they decide a couple of days or a couple of weeks that they . . .

I- Where would they get that water do you think?

S- Um, probably um, where did they get it from? Who did they get from?

I- Where?

S- Oh, like [in the] country? Like probably like, ok. Say it was back then. You know how they, like they give milk out to people by glasses. Probably they can do like that if they um had the water.

I- Ok. I don't understand what you are telling me right now.

S- I mean like, sometimes, um, you know, men or women can ride a horse like a chariot and they could pass out water to people. And these glasses. If there is enough, they will be able probably, be able to, probably able to plant there. I mean water their plants.

I- So are you are saying that's done now or that's done in the past, or what?

S- That's done in the past.

I- So what do they do now to be able to get water to the plants? Or do they do that? Do they just plant them and hope the rain?

S- I don't think so.

I- You don't think they just plant them and hope the rain. So how do they get the water to the plants?

S- They probably have in order to get the water, probably they have to pay for it or . . .

I- What is the source of that water?

S- I don't understand what you are saying.

I- Ok. So where do they get the water from?

S- They probably get the water from, from, from, from, from . . .

I- Tell me what it is. Maybe you don't know the word but tell me what it is.

S- It's like, say we are renting a house. They've got to pay for it and if people don't pay for, they're gonna to cut you off. And they're probably going to throw you out back onto the street, if you don't pay for rent. That's what I'm, I'm talking about like . . .

I- Like a water company.

S- Yeah, yeah, you have, don't you have to pay for it in order to get it? Or . . .

I- But the question is where it has come from though.

b. Fertilizers

The second portion of this benchmark dealt with reason why fertilizers were used to grow crops. Only Jay and Liz mentioned fertilizers during their interview. They

also both knew that fertilizers provided "stuff" that plants needed; they were coded Compatible-Sketchy. Jay said that farmers gave plants food through "little white pellets and sticks." When asked how he knew this, he said that his mother and he had used it in their garden. Liz' knowledge of fertilizers was also based upon her family experience. Fertilizers came up in a round-about-way. Liz was talking about what cows needed to be protected from and stated that they needed to be protected from fertilizers. She stated that fertilizers were used on lawns and that they helped plants grow and got rid of weeds. When asked if lettuce could be grown with fertilizers, she wasn't sure. She said:

> L- They eat grass, um, maybe they wouldn't let their cows to be poisoned or anything like with fertilizers, so the cows would get sick and die.
>
> I- You just talked about fertilizers, can you tell me what that is?
>
> L- A, ha--its something you put on your grass, um, sometimes it's so the weeds don't grow up, like the dandelions.
>
> I- What does it do to the grass?
>
> L- It helps it grow and makes it, um, I guess greener, so it doesn't look all burnt and dry. But other times, like if you use fertilizer and put it in a bucket, and just spread it around, it'll burn the grass because there's like too much in one spot. Like we have a spreader, so you put it in this big thing that's on wheels and it shoots it out of all the side, so where it goes to different places instead of one spot.
>
> I- So are there any other kinds of plants that use fertilizer, or is it mainly grass?
>
> L- No, we, at home, we use it on, sometimes on the rose bushes.
>
> I- Would you ever use anything like that on lettuce?
>
> L- I don't know.

The other elementary students were coded Nonexistent in relation to fertilizers as they did not mention them when asked about things farmers might provide plants to help them grow.

2. Obtaining common foods eaten by Americans.

Table 20 displays codings for the benchmark: identify the places of origin of common foods eaten by Americans. In this study, the two foods were lettuce and beef and they were dealt with separately.

a. Origin of lettuce

Tom, Jim, Tim and Ema held Compatible-Elaborate understandings of the origin of winter lettuce. Tracing this commodity back to its origin was quite telling of an informant's understanding of the relationship between climate and plant growth. The aforementioned informants stated that lettuce needed a warm climate to grow. They then went on to speculate as to where this climate might have been found. Tom stated that the lettuce was most likely grown in states like Georgia or Florida; or he reasoned, it could have been grown in a Michigan greenhouse during the winter. Similarly, Jim and Tim stated that the lettuce was probably grown in the southern US, while Ema reasoned that

the lettuce came from California because of its climate. Liz was coded Compatible-Sketchy because her description was in accord with the expert conception for the need for warmth, but then she seemed to make a reasoned guess as to the origin of the lettuce--she said South Africa because it has a different growing season than the US. Liz' reasoning is provided below:

I- So, where do you think it [lettuce] comes from, where does it come from during January?

G- Maybe from a different country where there's not the same seasons- I guess.

I- thought about that before? What you just a, or

G- No.

I- think about it then.

G- Ya. Well I guess because different countries, there's not the same schedule as us. Meaning they're not like on the same season, or day time, or the same, like um, like when it's winter here, it would be like summer in Africa [laughs]--which I don't know if that's true.

I- It's true, it's true.

G- Um, maybe they grow the plants through the same process in Africa-- they then would ship it over to the US.

The remainder of the informants were coded Nonexistent. Jill responded that she did not know where the lettuce came from, while Jay, Jill and Mona stated the lettuce came from "out in Michigan," "in state" or "here [Lansing] or in Detroit." This was not possible (other than in a greenhouse) as it was approximately 20°F when the interviews were conducted. Jay's comments were representative of the Nonexistent informants on this benchmark:

I: OK, now the lettuce and the pickles, where do you think they were grown?

J: ...Probably grown, here.

I: So, what was the temperature like here in Michigan last month?

J: Cold.

I: So, go ahead.

J: About in the...fifties.

I: OK, how do you think lettuce would grow in the fifties?

J: Not very good.

I: So, you still think it was grown here in Michigan?

J: (Shakes head) No.

I: Where do you think it was grown then?

J: Probably out in Detroit.

b. Origin of beef

The second part of this benchmark dealt with the origin of a common food that students, as a group, held more compatible understanding of--cattle. Tom, Jim, and Ema stated that cattle required large expanses of land and that these places could be in most

states or even in other countries; they were coded Compatible-Elaborate. Tom said the cattle were most likely raised in the western US in states like Montana or Idaho [where he lived previously]; Jim stated that the cattle came from Arkansas [where he had seen pictures of his cousin's house near a farm]; Liz said that the cattle came from Virginia [her uncle had a farm there]; Tim thought the cattle came from a desert somewhere in the west where they were held in cages, and finally, Ema suggested that the location didn't matter as long as there was suitable space.

Jay, Jill, Mona and Sara were coded Nonexistent. Jay said the cattle came from "here or in Detroit" as he did for the lettuce, while Sara based her reasoning of the origin of cattle upon visits to her aunts, "out in Michigan."

I- Where did the cows come from that made the meat?

S- Out in Michigan.

I- Why do you say, out in Michigan?

S- See my aunts, 'cuz they live out in Michigan.

I- Where do they live?

S- They live by this farm. On this farm, I don't know the streets. Like where it's called but all I know it's out in Michigan. I usually visit them sometimes they got this house in Detroit that we can go to, this yellow house and then we can go see them or if they are not there, they probably they can be out in Michigan, 'cuz they have two houses. Probably they still own them. Probably out in Michigan.

Jill and Mona said they had no idea about the origin of the "animals" that made the meat.

3. People obtain food from places with more suitable climates.

For the final benchmark in this section--which asked elementary students to describe how places too cold or too dry can obtain food from places with more suitable climates--all were Compatible-Elaborate. They all described transport systems that moved lettuce and cattle/meat from one location to another. All responses included trucks, while Tom and Sara integrated the use of planes and ships into their responses.

Summary/Discussion

All except one (1) student did not know the reason why crops were grown with irrigation. They mentioned part of the answer, that plants needed water, but did not add that humans often grow crops in unsuitable environments, such as winter lettuce in the desert. The informant who did know both reasons why irrigation was used had lived in a rural, arid area where irrigation was employed. The conceptions held by students, like in many of the previous benchmarks, were not misconceptions, but rather nonconceptions; their mental schemas were absent.

To an even greater extreme than irrigation was their dearth of understanding of why fertilizers were used. Only two (2) students spoke of fertilizers, although just one (1) used the word fertilizer by name. The informant who did not mention fertilizer by name held a misconception that people gave plants food in the form of "little white

pellets and sticks." Both students who mentioned these materials had learned of them from their parents in gardening and lawn maintenance.

Student conceptions of the origin of common foods were dependent upon knowledge and understanding of : 1) climate, 2) plant and animals growth requirements, and 3) geography. Four (4) students wove these concepts into accurate discourse about the origin of lettuce. They reasoned that the lettuce on the BigMac™ was grown in a warm climate--either in the south or west of the US. One student understood that lettuce required a warm climate, but guessed that it came from South Africa because she knew that they had the opposite temperature than Michigan.

Of most interest is that students who held no conception about the origin of lettuce came from urban areas. They lacked a geographic reference to reason where the lettuce could be grown. Also interesting is that, although they, in previous benchmarks, discussed warmth as a growth requirement, they did not relate the temperature in Michigan during February to the growth of crops--they appeared not to have integrated school-knowledge into a workable everyday schema for the origin of crops.

Relative to the beef, the majority of students understood that cattle required much land to graze and that this land could be virtually anywhere. Interestingly, all students--except one--who were coded CE for this sub-concept, were very specific about where cattle were raised. They referred to place where they had seen cattle themselves, or places where they had seen them in pictures or heard of from relatives. Those that were coded CS or N were all from urban areas. They seemed not to possess the same library of experiences from which to draw upon. Their urban background and their

parents lack of economic resources may have limited their geographic knowledge of and their experiences with seeing cattle.

In contrast to the benchmark on the origin of foods, all students understood that lettuce and beef were transported from place to place via truck. Much of the background for this benchmark was laid in benchmark I.A.3.--the journey of crops. It could be argued that students, because of their lack of knowledge of the origin of winter lettuce described previously, did not understand this benchmark. I placed emphasis on the obtaining through transport system aspect of this benchmark, not the climatic aspect.

III. Cultural-Historical

A. Social Change by Agriculture

The Cultural-Historical section examines one (1) key concept and one (1) benchmark corresponding to this concept. The key concept deals with human management of ecosystems and its benchmark focuses on how agriculture has changed society.

1. Effects of modern technology on farms, farmers and rural and urban communities.

Table 21 divides the benchmark *Explain the effects of modern technology on farms, farmers, and rural and urban communities* into three separate categories. For analysis,

each is ascertained separately. The analysis proceeds alphabetically as the categories are found in the table.

Table 21. Elementary Student Understanding of: III.A. How has agriculture changed society?

Benchmark	Jay	Jill	Tom	Jim	Mona	Sara	Tim	Ema	Liz
1) Explain the affects of modern technology on a) farms	N	N	CE	CS	CS	CS	CS	N	CS
b) farmers	N	CS	CI	CI	CS	CS	CS	N	N
and c) rural and urban communities.	N	N	N	N	N	N	N	N	N

ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy; CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate

a. Farms

This is a highly complex benchmark. The expert proposition for the effects of technology on farms included: 1) the increase in size of farms, 2) the decrease in number of farms, 3) the move toward specialization of crops produced, 4) the increasing complexity of farms, and 5) the increase in the mechanization of farming operations. Only Tom articulated an understanding of all five of these effects; he was as coded Compatible-Elaborate. Similarly, Tim and Liz stated that farms had become more specialized. Jim, Mona, Sara, Tim, Sara and Liz also understood that farms had become more mechanized, but they did not relate this to increased size, complexity, or decreased number; they were coded Compatible-Sketchy. Jay, Jill and Ema were Nonexistent in their understanding, they said they did not know how technology affected farms.

b. Farmers

Relative to understanding technology's effect on farmers, Jim and Tom's responses were Compatible-Incompatible (Table 21) when compared to the expert conception which included: 1) a reduction in labor, 2) dependency of technology, and 3) a reduction in the total number of farmers. Their coding as Compatible-Incompatible may be misleading as they possessed a greater breath of understanding than their contemporaries, but were confused and worked out ideas as they spoke. Tom's statements were contradictory. At one point he said that the number of farmers had increased, while later he reasoned that with more machinery, the number of farmers might be decreasing. He explained:

I- So do you think that there are more farmers now or less than let's say 70 years ago?

T- Probably more. Well, it could be more 70 years ago or it could, well, now they have more machines to make bigger fields. So it could be less, 'cuz sometimes farmers back then have to do it by hands not by machines. So it could have less farms out there. Or there could have more farms because they had lesser room to have farms.

I- Ok. So you are really, you are really not sure.

T- Yeah. I am not sure.

I- Ok. Um, let's say they do have more machines or bigger machines. So what are the advantages of that?

T- Well, it gets it done faster.

I- Ok.

T- You can have bigger field with it. And really it helps you, it can protect, some machines protect the plants, 'cuz those machines have a lot of, it has water like a thing goes around it with water. That kind of machine.

I- I think it's called center pivot.

Similarly, Jim answered that the number of farmers had decreased over the past 100 years. When probed about why this had occurred, he was unable to support his proposition. He eventually stated that he saw this topic on a Discovery Channel™ television program.

I- Do you think that there are more farmers or less farmers now than there were 100 years ago?

J- Less farmers now than it was 100 years ago.

I- How do you know that?

J- Because . . .

I- Or why do you think that?

J- Because farmers back, um, 100 years ago they had, they had to um. . . farmers back then, they, they, ok. There is a word I'm trying to say but can't get that.

I- Use another word.

J- Ok. Farmers, they were, they were like a lot. Farmers back then, they were a lot. Serious about their farming. And farmers now they just, well they're, well they're serious but they are not serious as the 100 year ago farmers.

I- Ok, so the question was is there more or less farmers now than 100 years ago. And you said less and then you said farmers back then were more serious but so farmers now are also serious. So what are you saying?

J- But they are not serious as they were.

I- Ok, so they were, how does, how does that relate to the number of farmers?

J- How does that relate . . . ?

I- To the number of farmers, 'cuz you said there are less farmers.

J- Because farmers now, they just, I've never thought about that.

I- Ok, well if you are real sure of your answer, I am just trying to figure out why you thought what you were thinking.

J- I can't think of nothing. I was trying to think of something.

I- Ok. Why don't you say that there are more farmers now?

J- Well, really, that was, that was my opinion.

I- Right, I am asking, I am trying to figure out why you had that opinion. Why do you think that there are, why do you think there are less?

J- Why do I think there are less?

I- Yeah,. You said that there are less farmers. So why do you think there are less farmers?

J- . . .

I- You want to go on something else?

J- Yeah.

I- Why did you think there are less?

J- I thought there were less because I never. Ok like on, I watch Discovery Channel sometimes.

I- Sure, it's a good thing.

J- And um. They show, they would show like farmers. There would be farmers everywhere, 'cuz they showed something about it. They showed a presentation about it. And it was, it was farmers everywhere.

I- Right.

J- Wherever we went, there were farmers 100 years ago. But now there is not a lot, there is not as much farmers as there was then.

I- Ok. The reason why you think that was because you saw them on Discovery Channel.

J- Yeah, because there were a lot of farmers.

I- So let me ask you this. Do you think that there is more or less food grown now than 100 years ago?

J- I think there is more food grown now.

I- Tell me about that. Tell me how, how that could be possible.

J- Because it took, it took like years and years and years for people with farmers 100 years . . . I mean, not years and years ago, but like a few years for foods to grow. But now people just go, I mean, they, they, they just . . . Can we come back on this subject later?

Additionally, Mona, Sara, Tim and Jill were coded Compatible-Sketchy. Mona, Sara and Tim implied that with mechanization, labor would be reduced, but made no link between this proposition and reduction the number of farmers or their dependence of technology. Tim commented:

I- So farmers have to buy their technology. What does the technology do for farmers?

T- It probably helps them out.

I- How?

T- Maybe, I am not so sure, the tractor is technology.

I- Say it is. How does it help them out?

T- It probably helps them like where the tractors pull those big towing things, instead of horses, where it evens out the crops and puts them in a line and they plant the seeds so where it can grow.

I- Ok. So, how would that help?

T- That makes sure the crops won't . . .

I- How does, how does that help from doing it over animals?

T- Well, probably helps some, because it puts plants in a straight line, and plants have a hard time growing (overlapping speeches).

I- You couldn't do that with a horse?

T- Well, you could . . .

I- So what's the benefit then?

T- Um, that sometimes you don't have to spend your money or something?

I- What do you mean?

T- Like because if you go out and buy a tractor and you have a horse and, you know, like . . .

I- No. I am saying what the benefit of using a tractor versus a horse.

T- One thing you go a lot quicker. Because you have to, like, you never know what the horse would do. Like it will stop, or go fast, or slow. But if you have a tractor, and you could make sure that it goes (inaudible). Like goes fast and slow. And you want it your way, not the horse's way.

I- So it saves time for the farmer and the farmer can do what he wants.

T- Yeah. And so he can get done other things, like chores.

Jill, on the other hand, stated that the number of farmers had decreased, but made no link to increased mechanization. She added, however, that there were less farmers because there were:

J- Better jobs and more of them.

I- So, OK, there are more and better jobs. So, when people don't have good jobs is when they are farmers?

J- What?

I- Well, you said that you think that there are less farmers today than 70 years ago because there are more and better jobs.

J- Yes.

I- So, do people farm then when there aren't good jobs or when they can't get good jobs?

J - (four second pause) Ah.

I- So why do you think there are less people farming?

J- (shrugs shoulders indicating no idea)

Finally, Jay was coded as Incompatible-Sketchy. He believed that the number of farmers had increased because there is now a greater number of people who enjoy farming, while Ema and Liz were coded as Nonexistent as they responded that they did not know the effects technology had on farmers.

Interestingly, when asked about technology, many informants spoke initially of computers. Tim broached the idea of computer technology and then said that computers were probably not used by farmers, because they didn't have any jobs--they made their own food:

> I- How do you think farmers have computers to help them out?
>
> T- They probably don't, because a lot of farmers probably, I don't know like . . . to, I, farmers probably don't, don't use all that much technology stuff.
>
> I- How come?
>
> T- Probably because they don't need it. They probably don't have any jobs. They get the food from the, probably the farm. They just, just going to cost them a lot of money and they don't need it.

c. Communities

In the last portion of this benchmark--agricultural technology's impact on communities--the depth of response was limited to an increase in food availability. This idea was held by Jill, Jim, Tom, Sara, Mona, Tim, Liz and Ema. This idea alone did not warrant a coding of anything other than Nonexistent, because they were not linking this to the effects increased food had on communities. Jay had no response to this question and was also coded Nonexistent.

When asked about the effects of technology on communities, Sara and Mona spoke at length about chemicals being placed into foods which reduced quality and made people sick. On the other end of the spectrum, Liz spoke about how much more healthful food was for people in communities today. She linked this proposition to the notion that preservatives were now added to milk and that machines aided in the reduction of harmful bacteria..

I- So how has that changed farms and farmers.

G- Probably helps the farmers out. They won't have to do such of a big job. Doesn't really affect anything with the farms, not that much, not at all really.

I- Ok, what about the community in which people live.

G- I don't know if they have anything to preserve the milk, so it's not bad or anything. I don't know if they drink it after they milk the cow, which I think they just drink after they milk the cow, put it into a different container--back then. And now, they probably find out that a lot more people are getting sick from milk.

I- A lot more are or aren't?

G- Are, because of the bacteria and stuff in it. Now we have, probably machines, that do all the different--I don't know.

I- Why do you think more people are getting sick now from milk?

G- No--I meant back then. Um, because they didn't have any like, machines to do, like take all the bacteria and stuff out of it.

I- How do you do that?

G- Guess you have to have some bacteria in there because it's good for you.

Summary/Discussion

Overall informants had difficulty in making cause and effect relationships between technology and farms, farmers and committees. This was manifest in their limited or lack of response to prompts. Relative to farms, only one informant's discourse matched the expert conceptions. This student--the only person with a rural background--was able to link mechanization with the five (5) effects detailed in the goal conception. Two (2) other informants knew that mechanization was linked to specialization of crops grown and increased in output of crops, but this was the extent of their understanding of the effects of technology. Similarly, five (5) other informants knew mechanization increased yield, while the remaining three (3) students had no conceptions for technology's affects. What was missing from these informants was the ability to make connections between technology and its affects on farms.

Likewise, the same basic notion held true for the sub-concept of farmers, but overall informant codes were less compatible with the expert conception. Two (2) spoke in conflicting ways about the effects of technology. One (1) informant was working out his understanding as he spoke, while the other was confused about what he had seen on a Discovery Channel™ program about farmers. The other informants understood that mechanization would help farmers make their jobs easier, but were limited to this effect, while another believed that more people had entered farming because they found it enjoyable. Still another believed that there were fewer people living on farms today, but did not have any reasons to support her statement. The remaining two (2) informants had no concept of technology's affect on farmers.

When extending the affects of modern technology onto communities, no informant's discourse was compatible with all parts of the expert conceptions. Students understood that technology increased the amount of food produced, but could not make the link to the effects this would have on rural and urban communities.

Two female respondents from Detroit both spoke at length about chemicals that are now added to food today that were not used in earlier times. They suggested that, because of these chemicals, food was no longer as good for people. Interestingly, an informant who had visited a university dairy farm held the exact opposite opinion because she believed that modern technology prevented contamination of food by bacteria. Her experience formed her opinion, while the beliefs of her urban contemporaries where based on what they saw on the media and what they heard from their families.

Of additional interest is that the young women who held such clear conceptions for canonical science knowledge displayed the same level of understanding as the rest of the informants when asked questions related to the effects of technology.

Research Objective 3. Prospective elementary teachers' understandings of the agri-food system goal conceptions.

This section describes prospective teachers' understandings of five (5) clusters of benchmarks for the elementary section of this study and two (2) for prospective teachers. As in the previous research objective, the clusters are organized around Key Concepts. Found within the key concepts are sixteen (16) individual benchmarks.

The analysis begins with elementary benchmarks which include: four (4) benchmarks related to a general understanding of the Agri-food system, eight (8) Science: Agricultural-Environmental Interdependence oriented items, and one (1) Cultural-Historical benchmark detailing technological effects on society. After presenting these findings, higher level results from prospective teachers benchmarks are presented.

Elementary (K-5) Benchmarks

I. Agri-food System

A. Concept of Agriculture

Table 22 lists the first cluster of benchmarks which are organized around prospective teacher informants' understandings of a key concept from section I. Agri-food System: What is agriculture? Four (4) benchmarks necessary to answer the key concepts are found in the table. Analysis of the benchmarks follows.

Table 22. Prospective Teacher Understanding of: I.A. What Is Agriculture?

Benchmarks	Sid	Kat	Moll	Kara	Di	Dan	Guy	Mer
1) Identify food and fiber products that come from plants and animals.	CE	CE	CE	CE	CE	CE	CE	CE
2) Describe the variety of farms and their products.	CE	CE	CS	CS	CS	CE	CS	CE
3) Describe the journey of a food or fiber product as it travels from the farm to the consumer.	CE	CE	CE	CE	CE	CE	CE	CE
4) Describe how agriculture uses natural resources to provide peoples' basic needs.	CS	CS	CS	CS	CS	CS	CS	CS

ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy; CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate

1. Food and fiber products that come from plants and animals.

As indicated in Table 22, all prospective teacher informants held a Compatible Elaborate understanding of the origin of the lettuce and meat found on the cheeseburger. They talked at length about the lettuce being a plant that grew in the ground and the meat coming from an animal; they all mentioned that the meat came from a cow.

2. Variety of farms and their products.

In coding informants, Sid, Kat, Dan and Meri held Compatible-Elaborate understandings of this benchmark as indicated by their knowledge of the size of farms and their specialized nature. On the other hand, Molli, Kara, Di and Guy held Compatible-Sketchy understandings based upon their understanding that lettuce came from a large farm, but the notions, in the case of Molli, Kara, and Di, of farms that grew multiple crops all in the same field.

All informants stated that the farm that produced the lettuce was most likely large. Their understanding of this relative terms varied from individual. Sid, Kat, Kara, Dan and Meri all believed that the farm was in excess of twenty (20) acres (they were told that a football field was about the size of an acre and used this as a basis for discussion). Although Di and Molli stated that the farms were large, Di said that the field where the lettuce grew was about ten (10) acres, while Molli thought it two to three (2-3) acres. Guy stated that he had no idea about the size of the field.

Relative to the diversity of crops grown on modern farms, Sid, Kat, Dan and Meri stated that lettuce was probably the only crop grown on the farm. This was in contrast to the ideas held by Molli, Kara, and Di. These three informants described the farm like it was a large garden. Guy did not mention anything about other crops being grown with the lettuce. Kara stated:

> I would assume they would have a lot of vegetables, I would assume--they would--and this is from what we grew when we were at our garden--have lettuce and carrots, tomatoes. I sure it would be mostly vegetables, like ground vegetables.

Di, in her conversation about the farm that grew the lettuce, said that:

I- So let's go back to where it started out, to

D- the farm [overlap of speech]

I- Can you tell me a little bit about what that place looked like?

D- Sure, I picture a farm with lots of acres, probably different crops too, but, um [someone] who makes his living off of farming and just tons of little heads of lettuce sticking out of the ground.

I- OK, then a football field is about the size of an acre, how many football fields was that?

D- I would say 10 maybe.

I- And you said that there were probably other things being grown about it. Can you tell me about that?

D- I would think that he probably won't make his living solely off of lettuce, but maybe he does. But I'm picturing just various other vegetables, maybe corn or onions or something like that.

I- And you said that you don't think that they would make their living off of just one thing--why not?

D- I guess I don't hear a lot about lettuce farmers, I mean, maybe wheat, I would think that would, you know, I just picture lettuce as having other crops grown with it.

3. Food or fiber product's journey from farm to consumer.

Generally speaking, all informants understood that lettuce was grown on farms, processed in some way and transported to the consumer. Not all prospective teachers understood all the intricacies of the journey that lettuce traveled from farm to consumer, but they had a notion of the basic system. They were all coded Compatible-Sketchy. Specifically, all informants understood that lettuce was grown on a farm. Also all expect Guy and Sid believed that the lettuce was shipped via truck to a plant for processing-washing, cleaning and shredding. Guy believed that the lettuce was transported via plane to a mid-western processing plant for distribution, while Sid stated that the lettuce was packed on the farm. He provided a very detailed and descriptive account of the journey that lettuce travels from the farm to the consumer.

I- Tell me about the lettuce.

S- Lettuce , um, let's still say that it was grown in Michigan, um, the same process I guess. It has to be planted, grown, raised, harvested, and then, cultivated, picked, whatever, and cleaned and washed, crated into boxes, maybe checked over, make sure, no bugs or it hasn't been [inaudible].

I- Where's that going to be done?

S- Um, probably be done right there on the farm.

I- Ok, and the cleaning and washing stuff, also right there on the farm?

S- Ya, sure, then they would ship that somewhere, probably to a food service company who purchases the lettuce from them, a giant food service company, I guess, and they would ship it by truck or train.

I- Can you tell me a little about the giant food service company, do you have any ideas about that?

S- Can't think of it right now, somebody who specializes in purchasing stuff for crop distribution and distribution center. Um, maybe--Gorden's Food Service. I think they'd be considered a middleman, they get food for places and package it and ship it to certain restaurants and businesses.

Besides Sid, all prospective teachers stated that the processing plant prepared the lettuce for consumption. Interestingly, both Molli and Sid stated that the lettuce could be frozen for shipment at a later date. From the processing plant, all informants except Molli and Sid believed that the lettuce was shipped directly to restaurants. Molli and Sid both discussed the need for a broker or middleman to orchestrate the distribution of the lettuce.

4. Agriculture uses natural resources to provide people's basic needs.

All informants knew that plants and animals required natural resources to grow and, hence supply humans with food and fiber products from plants and animals. All stated, except Guy, that plants needed soil, water, and the sun in order to grow. Guy, on the other hand did not talk about soil as a requirement for plant growth. Interestingly, all informants neglected to discuss air (Oxygen and Carbon dioxide) as a natural resource necessary for plant growth. As a result, all informants were coded Compatible-Sketchy on this benchmark.

Summary/Discussion

All prospective teacher informants understood that plants and animals were the source of food--in this case the lettuce and meat.

Their ideas about farms were not as consistent, however. Four (4) of the eight (8) prospective teachers understood that most modern farms were large in size and specialized in the crops they produced. Four (4) informants stated that farms were large, but described them much like large gardens, with multiple crops growing in rows next to one another. Prospective teachers described farms as large, but their estimates of size (using football field sized units as a measure) was lacking in comparison to the vast expanses of monoculture agriculture. In addition, descriptions of farms seemed to be based on personal experiences.

All informants understood that crops made a journey from the farm to the consumer and that journey involved transport, processing, and delivery of product. Although they were not extremely detailed in their descriptions of the journey, all showed a rudimentary understanding of the system. Only two (2) informants spoke of a broker or middleman who orchestrated the linkage between buyer and seller.

Prospective teachers were sketchy in the details of what natural resources were required to provide for people's basic needs through agriculture. Although all--except one (1) -- mentioned soil, water, and sun as natural resources necessary for growth, no informant added air as necessary for life. It seemed that prospective teachers had memorized soil--water--sun, but did not think deeply about these resources. As stated

previously in this dissertation, limited understanding of natural resources has been documented by science education researchers for years.

II. Science: Agricultural-Environmental Interdependence

The Science: Agricultural-Environmental Interdependence section examines three (3) key concepts and eight (8) benchmarks corresponding to the concepts. The key concepts include: A. Ecosystem Management, B. Crop Management to Promote Growth, and C. Role of Science and Technology in the Agri-food System.

A. Ecosystem Management

Student codes for the key concept pertaining to ecosystems management and its supporting benchmark are displayed in Table 23.

Table 23. Prospective Teacher Understanding of: II.A. How are parts of the ecosystem managed by humans, and how do they interact?

Benchmarks	Sid	Kat	Molli	Kara	Di	Dan	Guy	Meri
1) Describe how crops depend on an area's a) climate and	CE	CE	CI	CE	CE	CE	CE	CE
b) soil for growth.	CS	CS	CS	CE	CE	CE	CS	CS

ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy; CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate

1. Crops depend on climate and soil.

a. Climate

All informants, except Molli, were coded as Compatible-Elaborate for understanding of climate. They stated that a specific climate was necessary for the growth of crops such as lettuce. Climate was defined by them as temperature and rainfall. Their responses were not as well developed and deeply rooted as the goal conception, but they definitely understood the connection among climate and plant and animal growth. Originally Molli was coded Compatible-Elaborate for climate; she gave the appropriate response. Upon further probing, though, she showed that she really didn't consider climate and temperature when it came to the origin of winter lettuce, or at least, her response that lettuce in January came from Indiana, drew her initial coding regarding climate into question; she was then coded Compatible-Incompatible. On the other hand, Guy articulated the most well founded understanding of the climate concept when he explained that the lettuce probably grew in California because of specific climatic conditions found there. His statement was based upon a class he took in geography at Michigan State University. Meri also took the same class and held similar ideas. Their discourse about climate and its relationship to plant growth was much more extensive and specific than the other informants. Guy commented:

G- I would think the lettuce was grown somewhere, probably, I don't know, I'd say maybe California. Although knowing McDonalds, it might be out of the US, so I don't know, but

I- Why do you think California?

G- Because from what I know about--let me think, see, I had class in this a while ago. I believe most of the lettuce is grown in California, because of the climate. But I might be wrong, that was a few years ago. So that's my best guess.

I- When you said Mediterranean climate, what do you mean by that?

G- Um, they get the, let me see, temperature-wise, like, it's like, um, let me think, um, and they have, um, well they get the climate [from] the water and they get the continental climate from the north. So they have a little of both, I guess. Just like Florida. Actually, I'm kind of confused on it, so.

I- So, OK, it was grown in California. Could it be grown here in Michigan?

G- I don't think so, actually I'd say no.

I- How come?

G- Um, because, I believe lettuce has to be grown in a more moderate climate, not a, I'd think it too cold, we don't have enough months above the critical temperature point, which I would think is like 60 to 70 degrees, from what I, so I don't think it would be grown here.

b. Soil

All informants spoke of soil as necessary for plant growth. Upon deeper probing, though, only Dan, Kara and Di said that soil provided minerals for plants, a place for roots to anchor and hold water. Other informants simply stated that soil was necessary for growth with no elaboration, this is underscored in Benchmark II.B.1).

Summary/Discussion

All prospective teachers--except one (1)--stated that a specific climate was necessary for plant growth. They described climate involving temperature and precipitation. The one (1) informant who did not understand climate's link to plant growth stated that lettuce grew during the winter in Indiana. She did not link temperature to plant growth and simply thought that Indiana was where farms were.

An understanding of soil's role in growth was not as universally held. Three (3) of the eight (8) prospective teacher informants expressed understanding of all three aspects of the expert's conception, while the five (5) others only stated that plants needed soil and included no elaboration. As stated in the elementary student section of this paper, an understanding of what plants derive from soil undergirds an understanding of why fertilizers are used and the trade-offs of such technologies. It is apparent that the majority of prospective teachers in this study do not have a deep understanding of this concept, and as such, their understanding of more complex ideas about agriculture will most likely be hindered.

B. Crop Management to Promote Growth

The second key concept under the rubric of Science: Agricultural and Environmental Interdependence involves the management of crops to promote growth.

There are four (4) benchmarks found in Table 24. They cover the requirements for plant growth, how crops are lost to pests, pest management, and the impacts of using poisons (pesticides) to protect crops.

Table 24. Prospective Teacher Understanding of: II.B. How do humans manage crops to promote growth?

Benchmark	Sid	Kat	Molli	Kara	Di	Dan	Guy	Meri
1) Describe basic growth requirements for plants and animals.	CS	CS	CS	CS	CS	CS	CS	CS
2) Describe how crops may be lost to pests.	CS	CS	CS	CS	CS	CS	CS	CS
3) Explain how crops are protected from weeds and pests.	CS	CS	CS	CS	CS	CS	CS	CS
4) Describe the positive and negative impacts of using poisons to protect crops.	CS	CS	CS	CS	CS	CS	CS	CS

ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy; CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate

1. Basic growth requirement for plants and animals.

Table 24 indicates that all prospective teachers were coded as Compatible-Sketchy in reference to the growth requirements of plants and animals. This is a K-2nd grade benchmark in the AAAS Benchmark document. Therefore the depth of understanding necessary to meet this benchmark is relatively shallow. None of the interviewees articulated a well developed understanding of the canonical scientific requirements for growth and maintenance of living things. All informants except Guy mentioned soil, water, sun, and temperature as necessities for plant growth. Guy did not mention soil as has previously been noted. No informant discussed space or air as a need for plants. Similarly, all informants stated that water and food were necessary for animals to live. Air was mentioned by only Meri, Guy, and Di, while space was discussed by Kara and Kat. Finally, specific temperature requirements for animals were proffered by Meri, Dan, Kara, and Molli.

The range of understanding of growth requirements for plants is representative in the discourse of Kat and Guy. Kat held the richest and most highly developed schema:

I- Tell me about the light.

K- The light, does chlorophyll, turns into glucose, and --- I had biology last semester and I should know that.

I- OK, what does it do then?

K- It's the energy for the plant, how it grows or produces, fruit, sugar ...

I- So tell me how that works.

K- I have no idea. My mom is a science teacher, she would shoot me if I didn't know how that thing works.

I- What does the water do?

K- Well the plant needs water.

I- For?

K- For the same reason we do, for a, so we don't get dehydrated.

I- OK

K- You can tell I know a lot about plants, can't you!

Guy's understanding of plant growth needs was also based on a similarly disjointed and incomplete schema. Upon the initial prompt he mentioned that he only knew water and light, "and that's all I know," but when probed further, he mentioned bits and pieces of information related to the needs of plants:

I- What is it that plants need in order to grow?

G- I know they need light; they need water, and that's all I know.

I- Can you tell me a little bit about what the light does?

G- I think the light just provides the energy for the processes to take place--like photosynthesis and that's about it.

I- What happens in photosynthesis?

G- Um, that's where the--I'm drawing a blank now--um, something to do with the food, I think. It's not repro; I don't think it's reproducing? I don't know.

I- What about the water, what does the water do?

G- The water keeps the plant at a level where it's healthy, so it does not dry. And water enables it to grow.

I- How?

G- I guess whatever it does to trigger the systems, to trigger the stuff inside the plant to grow. It just helps the cycle run whatever the growth cycle is in a plant. I'm not sure about plants.

I- So plants need light and water, anything else to grow?

G- Um, I know chlorophyll. I guess they need a lot of things. There's all that stuff inside of a plant, I guess, but I don't know if that's what you mean now.

2. Describe how crops may be lost to pests.

Table 24 reflects that all informants were Compatible-Sketchy in their understanding of how crops may be lost to pests. All informants, except Guy, understood that crops could be lost to insects and other animals, such as rodents and deer. Guy spoke only of losses due to insects. Di, Dan, and Kara specifically stated how these might take place: eating of plants while growing or the nesting of insects in the crop. No informant spoke of losses to crops after harvest.

Only Sid, Di, and Dan spoke of weeds affecting crop growth negatively. Di was the only informant that proffered a reason for these losses--the competition for minerals by weeds with crops. She stated:

D- Well, I know in gardens you weed. I don't know if you would have to do that in a big sort of field with any machines, but I'm assuming you'd wanta keep other little plants from taking the minerals from the soil [questioning, nervous laugh].

I- OK is there anything else that those little plants might do, take the minerals from the soil, anything else?

D- Um, maybe attract other bugs, but I can't think of anything else.

It is noteworthy that no informant spoke of competition for space and sunlight between weeds and crops.

3. Explain how crops are protected from weeds and pests.

As indicated in Table 24, all informants were Compatible-Sketchy in their understandings related to crop protection. In the expert conception for this benchmark, three (3) methods were listed to protect crops: 1) establishing barriers to animals, 2) killing of pests with poisons (pesticides), and 3) breaking the life cycle of pests through management techniques. No informant spoke of all three methods. Dan and Meri understood that barriers and pesticides could be used to control pests, while the others--except Di--all stated that pests could be killed with pesticides. Meri had first hand knowledge and experience with pesticides that led her to strong beliefs about their use. She stated:

I- Can you tell me a little bit more, you talked about bugs, and you talked about, um, did you say insecticides

M- Ya.

I- or pesticides?

M- Well I don't know if there's a difference.

I- Tell me a little about that

M- What I know or how they would use them?

I- Both.

M- Well they would probably just spray it on the fields with tractors that pulls one of those big tanks and spray it on the lettuce.

I- You've seen that before?

M- Ya.

I- Where at?

M- In Lapeer, basically so the bugs don't eat the lettuce. They spray broccoli; they spray; they spray everything, um, I don't like the idea that they spray everything.

I- How come?

M- I mean you're eating the pesticides, I mean, would you rather eat bugs or pesticides? It's kind of gross to think about it , but at least the bugs won't kill ya in the long run.

Kara also had experiences that led her to a fairly deep understanding how humans control and manage pests. She believed that insects knew that crops sprayed with pesticides were toxic. She commented:

I- How do they do that, the pesticides?

K- They're toxic.

I- Meaning?

K- Meaning they'll kill um. Like the insects don't go by them because they know that they are toxic. Like they will die from them.

I- They know that?

K- They figure it out, I guess. I don't know. They help some.

I- You talked about other things they might need to protect them [crops] from. Can you talk about that?

K- Well, like we had beans, and like all the wood chucks would eat. You know, I mean, so like small animals like that I know and rabbits. I don't know what else.

Di mentioned nothing about pesticides, but did speculate that weeds might be controlled by the use of machines in large fields. Sid mentioned that weeds could be controlled with herbicides:

I- Ok, you talked about rabbits a while ago and protecting it {lettuce] from rabbits. Is there anything else they would need to

S- Um, I guess pesticides maybe, herbicides. Stuff to keep weeds out, certain bugs maybe.

I- Why would that be important?

S- Well, possibly of destroying their crop.

I- Ok, and what would be the significance of that?

S- Of having the crop destroyed? Well, they wouldn't make any money and we might not be able to eat McDonalds™ hamburgers.

4. Positive and negative impacts of using poisons to protect crops.

Table 24 notes that all informants held a Compatible-Sketchy understanding of the positive and negative effects of pesticides (poisons) to protect crops. This benchmark is very complex and entails multiple subconcepts. The expert proposition includes both benefits and liabilities. Benefits include: 1) reduction in labor, 2) increase in crop yield, and 3) decrease in human disease. On the other hand, liabilities include: 1) expense of pesticides to farmers and ultimately to consumers, 2) pest resistance to poisons, 3) contamination to the environment and with it, death and morbidity to living things, and 4) decrease in the use of sustainable practices based upon a reliance on pesticides. No informant articulated an understanding of all these trade-offs.

In regard to benefits, all informants understood that pesticides could contribute to the production of greater crop yields and greater profits for the farmer. Only two of the informants had further understanding of how these poisons might benefit humans. Di stated that pesticides could reduce human disease and Meri spoke of decreasing labor costs through their use.

In regard to negative impacts of pesticides, informants' discourses were relatively extensive in comparison with other benchmarks in this key concept. All informants, except Di, mentioned that pesticides could cause contamination to the environment and might be detrimental to living things. Guy, Kara, Molli, and Kat mentioned that certain pesticides caused cancer in humans. Similarly, Dan, Sid and Meri mentioned death and morbidity in other animals, but did not specifically mention human beings. Only Di mentioned the expense of pesticides to the producers of food. She also mentioned that people were fearful of pesticides; this, she said, was a problem. Listed below are responses illustrative of the informant's ideas about the impact of pesticide use.

Kara had a well developed schema for the impact of pesticide use. She understood that pesticides were either organic or inorganic, that some were harmful to humans, reduced labor, cured bugs, led to protection of a crop, and there was an economic incentive for their use.

I- Tell me a little about this thing with pesticides.

K- The pesticides are things--either natural or whatever--that cure the bugs.

I- OK, why would that be important?

K- So that the farmer's crops weren't destroyed by a plague of locusts.

I- OK, and then why would that be important?

K- Because if you didn't have any lettuce you wouldn't make money and you'd lose the farm.

I- OK, how about more broadly speaking?

K- We won't have any lettuce for our BigMacs™.

I- OK, you talked about insects and insecticides--can you think of--what are the positives things, what are the positive things about that?

K- They're good because they protect the lettuce and that's good, some of them are cancerous or bad for people, some are bad for the environment.

I- How do you know that?

K- Just from the news or whatever, and just know that pesticides, and like the water, whatever that's, probably not such a good thing.

Molli was concerned that the use of pesticides would result in contamination of food. She spoke about the motive behind the production of food and stressed that economics was a driving force, not health.

I- Ok, how about anything that would be a trade-off, a negative, a liability of using [pesticides].

M- Well, they can cause, like perhaps, disease on the food.

I- Ok, what do you mean by that.

M- Like, um, well any chemical on food isn't healthy for you. So, if its too many chemicals someone can get sick from it. If its not cleaned properly, you know they have the risk of people getting sick and lawsuits, or just people not using their business anymore.

I- So with that possibility, why do we use them?

M- I think people are just more concerned with selling the food and getting it out. You know, the selling and buying aspect. They actually, I mean, this isn't a healthy meal [pointing to a BigMac™], but they want to sell it to people and they will sell it anyway they can.

Both Sid and Meri mentioned that crops could be grown organically, instead of using "chemical" pesticides. Sid stated that he didn't consider the use of pesticides in the production of the food he ate, while Meri was conscious of pesticide use and had purchased organic food herself. She believed that organic pesticides were less harmful than those from inorganic, human-made origin. Sid's and Meri's comments on organic food and pesticides follow:

I- And why would people choose to do that?

S- Grow things organically? Um, I guess because it's better for the environment and a lot of people just think that it's a lot better, it just tastes a lot better if they don't use pesticides.

I- So, if there are some positive things that come from the use of, let's say of pesticides, and there are some negative things, why do you think that people use them?

S- Um, well I guess that people use them see more of a positive side than a negative side. I guess either that or they just don't care? And I guess they use them because it does, benefit them in the long run and cuz [inaudible] they come out with better crops and will make more money.

I- And what about the people who eat the food?

S- Um.

I- Do they consider that, is it a big deal?

S- I don't think too many people take it into consideration. I know I don't when I bite into a hamburger; I don't think what pesticides were used in the production of the bun or lettuce.

I- And how come?

S- Cause, I guess, it's never affected me or never really occurred to me? I guess if it's not harming me then.

I- And how would you know if it was or wasn't?

Meri

I- So there's a problem with the pesticides then?

M- Well, if they're not some type of organic pesticide, if they're spraying something on there so the bugs won't eat the lettuce, do you want to eat the lettuce (laughs).

I- So why do they do it then?

M- Because it looks nice so they can sell it.

I- OK, what would happen if it wasn't used?

M- The pesticides? Well you'd probably get lettuce with some holes in it, maybe some bugs, you'd probably just have to wash it better and [trailed off].

I- How do you think people would feel about that?

M- Well they probably would, a lot of people don't like to take the time to cook in the first place so, I mean, if you're just buying prepackaged, cut up salad, ready-to-go, then, you know, you don't know what's been sprayed on it. But if you're growing something organic, you have to take the time to, I mean, if you're already buying it organic, then you're already considering what you're doing, so you take the time to clean it.

I- And do you buy, do you personally buy organic food?

M- I have.

I- Tell me, what's organic versus inorganic food?

M- Well all food is organic.

I- OK

M- You mean been sprayed?

I- I don't know, what makes it organic?

M- Just that it was grown without pesticides, that a synthetic element wasn't added to it.

I- OK, and why do you do that, why have you done it?

M- Bought organic food? Well usually it's fresher, because if you get it, um, I usually buy it in the summer, when I live in Lapeer, they have like a farmers market and stuff, so well it 's local, so you know, it's fresher. It

> hasn't been sprayed. you know, then, you're not digesting all those chemicals, or ingesting.

Summary/Discussion

Informants' understanding of how humans manage crops to promote growth were generally shallow and not well articulated through discourse. In the first benchmark, all but one (1) informant understood that soil, water, and the sun were needed for plant growth. They, however, did not speak to the requirements of space and air for plant growth. For animal growth, all informants mentioned water and food. Three (3) spoke of air, while two (2) said space was necessary for animals. Also included by four (4) of the eight (8) informants was temperature. Prospective teacher informants, then, did not possess a well founded understanding of what is necessary for the basic growth requirements of plants and animals.

In the second benchmark--crop loss to pests--all informants, except one (1) mentioned insects and other animals ate crops. On the other hand, only (3) informants mentioned weeds as pests for crops that limited production. And of these three (3), only one (1) mentioned competition between weeds and crops for space and sunlight. This is significant, because weeds are a major deterrent for crop production, but the majority of prospective teachers did not mention them.

The third benchmark dealt with crop protection. Again, the understanding of this topic was quite limited among informants. No informant spoke of all three methods of crop protection listed in the expert conception. Two (2) spoke of barriers and pesticides to protect crops, while (5) exclusively mentioned pesticides, and one (1) did not state any methods for protecting crops. It is noteworthy that only one informant mentioned herbicides, a major component of pesticide use on farms. Also noteworthy is that several informants held misconceptions about pesticides--they believed that they were repellents like those used to ward off mosquitoes and that "insects figured out" not to go near plants sprayed with pesticides.

The final benchmark concerned the positive and negative impacts of using poisons (pesticides) to protect crops. In this case, as with the other benchmarks under this key concept, informants held incomplete conceptions. First, all informants understood that pesticides benefited farmers by increasing crop yield and thereby increasing profits. However, for all of the informants, except two (2), this was the limit of their understanding. In the two (2) more complete conceptions, one (1) discussed decreases in human disease that accompany pesticide use, and one (1) mentioned a reduction in labor to farmers.

On the other side of the coin, negative impacts of pesticides were better understood. All, but one (1) prospective teacher understood that pesticides could contaminate the environment. Four (4) of these also included that certain pesticides caused cancer in humans and three (3) limited their responses to the death and morbidity of animals. Only one (1) respondent mentioned the expense of pesticides to farmers as a impact.

Deeper levels of understanding of this benchmark appears to be linked with experiences held by informants. For example, the informant whose father was a farmer described both positive and negative impacts of pesticides in detail. On the other end of the spectrum, an informant from Detroit who had never grown a garden was the most suspicious of pesticide use and questioned the motivations of those who used them. Interestingly, two (2) informants mentioned the production of organically grown crops and one (1) even purchased it.

C. Role of Science and Technology in the Agri-food System

The next Science: Agricultural-Environmental Interdependence related key concept deals with understanding the role of science and technology in the agri-food system. There are three (3) benchmarks foundational to developing knowledge and science and technology's role.

1. Irrigation and fertilizers.

Table 25 reflects codings for why irrigation and fertilizers are used to grow crops. Because this is actually a two part benchmark, analysis was broken into its two components: irrigation and fertilizer.

Table 25. **Prospective Teacher Understanding of: II.C. What Is the role of science and technology in the agri-food system?**

Benchmark	Sid	Kat	Moll	Kara	Di	Dan	Guy	Meri
1) Explain why a) *irrigation*	CE	CE	N	CE	CS	CE	CS	CE
and b) *fertilizers* are used to grow crops.	CS	CS	IE	CE	N	CE	IE	CE
2) Identify the places of origin of common foods eaten by Americans: a) *lettuce*	CE	IS	IS	CE	CE	CE	CE	CE
b) beef	CE	CE	CE	CE	CE	CE	CE	CE
3) Describe how places too cold or too dry to grow certain crops can obtain food from places with more suitable climates.	CE	CE	CE	CE	CE	CE	CE	CE

ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy; CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate

a. Irrigation

Regarding the irrigation subconcept, five (5) informants, Sid, Kat, Kara, Dan and Meri, understood both that a constant supply of water is necessary for plant growth and that humans grow crops in places that are oftentimes unsuitable for crop production. Kate, rather succinctly, explains why irrigation is needed:

I- What is this irrigating, it's the first time I've heard that word from you--tell me about that.

K- It's where you water the, it's like they have these big sprayer things that go over the entire field and spray water.

I- Why would you need to do that?

K- Because sometimes it doesn't rain all the time, so and the plant always need water.

I- And if you didn't have that.

K- The plants would die.

I- And as a result...

K- If you're the person growing it you're kind of screwed , because you don't have a product to sell.

Di and Guy were Compatible-Sketchy and stated that water was required for growth, but did not connect this with the unsuitability of the environment, while Molli mentioned neither and was coded Nonexistent.

b. Fertilizers

Reasons for fertilizer use were also analyzed. Kara, Dan, and Meri stated that: 1) plants required minerals for growth, 2) increasing the available minerals with fertilizers increases yield, and 3) modern monocultural practices--lack of crop rotation--necessitates the use of inorganic fertilizers; they held Compatible-Elaborate understandings of this benchmark subconcept. Dan's ideas about fertilizers represent a deep understanding of the topic. He was able to draw upon previous knowledge to extend beyond the anticipated response and spoke of soil fertility, organic verse inorganic fertilizers and their costs and benefits. His response included:

I- You talked about raising a crop and then its productivity declining. Typically, what would a farmer do in that case?

D- I guess he'd have to, they'd have to, sit back and assess why the productivity is declining. Is it because of the land, you know, fertility is leaving the soil. Is it because of maybe weather conditions, is something else [inaudible].

I- If the fertility was leaving the soil what oftentimes [overlapping speech].

D- They could boost up with fertilizers, maybe let the land stay in set-aside and pump matter, fertilizers, organic matter back into the soil.

I- Any drawbacks from that?

D- Well if you're using like artificial fertilizers of course that could leach in the water supplies. It depends on what you're using, if you're like maybe, like maybe a cow manure for example, if you're not a farmer that, you know, if you don't have access to that--if you're not a cattle farmer, I mean, where are you going to get access, are you going to buy it from a cattle farmer? You know, um, could there be a cost in transporting that type of material and then what's the effects. I know it's good for the soil, but what does it do to the water supplies or anything out of that, could leach into the water supply and hurt it, from maybe a river that could be nearby, or well water that could be going to the farm house.

Sid and Kat were coded Compatible-Sketchy. They stated that an increase in needed nutrients would increase growth and the plants would become greener. Sid spoke at length about Miracle Grow™, but did not find the word to call it a fertilizer. He understood that it added nutrients for plant growth. However, he was confused about the difference between a fertilizer and a herbicide.

S- I guess things do grow a lot better, faster anyway, bigger with pesticide and Miracle Grow™.

I- What is Miracle Grow?

S- Miracle Grow is, I don't know, a type of chemical, I'm not sure exactly what it's made of, but it's sprinkled on a lot of peoples' home gardens. Helps things grow faster.

I- Where did you learn about that?

S- Gardening in my backyard. My Mom used to put it on.

I- So, your Mom has a garden when you were growing up?

S- Oh, ya, we've always had a garden.

I- And you used to help there?

S- Ya

I- What does that Miracle Grow do then?

S- Well, I guess it soaks into the soil, into the roots, and then it supposedly is a nutrient for the plant, to enable it to grow--faster, stronger.

I- So is that, what is that called then, generally, what is it called?

S- Cheating! [we both laugh] I don't know what do you?

I- Well is there a classification, I mean, what do you , what is Miracle Grow called?

S- Pesticide, herbicide, I guess pesticide.

I- And how does that differ from a fertilizer?

S- Um, I don't know really. I guess a fertilizer, they both do the same thing, um, herbicides. I'm not sure how they differ.

Guy spoke of growth promoters that were akin to human steroids, while Molli said that fertilizers speed up growth processes and made plants skip natural growth steps; they were both coded Incompatible-Elaborate.

Di was coded Nonexistent as she stated that fertilizers helped plants grow, but had "No idea" about what they did to the plant. She did not attempt to offer any additional information about fertilizers.

2. Obtaining common foods eaten by Americans

Table 25 displays codings for the benchmark: identify the places of origin of common foods eaten by Americans. In this study, the two foods discussed were lettuce and beef and they were dealt with separately.

a. Origin of lettuce

As Table 25 indicates, Sid, Kara, Di, Dan, Guy, and Meri were coded Compatible-Elaborate in their description of the origin of the lettuce, while Kat and Molli were Incompatible-Sketchy. The Compatible-Elaborate group stated that the lettuce needed to grown in a warmer climate than was present in Michigan during the winter. Di, Guy and Meri were very specific about the origin of the lettuce--Meri and Guy stated that it was grown in California, while Di said Mexico. California or Mexico were the most accurate of possible answers for the origin of lettuce. Both Guy and Meri stated that they learned about the origin of lettuce in a geography course at Michigan State University.

Sid, Kara, and Dan said that lettuce came from a southern state which is plausible, but not as likely as California. Dan suggested:

D- Typically, I would say that, I mean, how it affects, I mean, you wouldn't be able to get the resources, you wouldn't be able to get the products--lettuce, cucumbers, out of the northern states. But you'd also have good southern states in the United States, for example, that can still produce this time of year.

I- So where do you think the lettuce came from?

D- Maybe came from someplace like Georgia, you know, Alabama. Some place, they still get a fair amount of rain, some decent weather, but yet, can produce, it's not an extreme climate, where they can't produce.

I- Extreme meaning?

D- Too hot, you know, too dry.

The two informants labeled Incompatible-Elaborate--Kat and Molli--seemed not to consider the climatic conditions in relation to the origin of winter lettuce. They spoke of crops coming from farms in the plains states like Nebraska, North and South Dakota; they seemed to simply know that many farms were located in this region. Plains states had farms; therefore, that is where the food comes from.

b. Origin of beef

Table 25 shows that all informants were coded Compatible-Elaborate relative to the origin of the meat. They said the cattle required much land to grow. Sid, Kat, and Meri stated that the cattle were most likely raised in the western US or in Central or South America. Dan and Guy also said that beef could come from the southern Americas. Dan went on to say that beef could be raised virtually anywhere, while Guy said that all McDonalds beef was raised in Brazil; he based this on a protest he witnessed at a East Lansing McDonalds' restaurant. Molli and Kat kept with their reasoning held relative to the origin of lettuce. They said the beef cattle were raised in the plains states. Di's answer to the origin of the meat on the BigMac™ was Ohio as she had seem a lot of cattle there while on vacation.

3. People obtain food from places with more suitable climates.

In the last benchmark in this section, all prospective teachers held a Compatible-Elaborate understanding of the need for food to be transported from one geographic location to another (Table 25). They all also mentioned that trucks were used to transport lettuce and beef. Sid, Guy, and Meri stated that other methods, besides trucks, were used to move food along its journey from the farm to the consumer.

Summary/Discussion

The majority of prospective teachers understood why irrigation was used to grow crops, while two (2) mentioned only that water was needed for plant growth and ignored the fact that humans increasingly grow crops in unsuitable environments where rainfall is lacking. One informant mentioned the notion of providing water to plants. This subconcept may have been relatively easy for most to understand, as they understood that water was a basic growth requirement. On the other had, a minority of informants understood why fertilizers were used. Only three (3) met the goal conception by stating that fertilizers: 1) increased minerals in the soil, 2) increased minerals added to plant growth and crop yield, and 3) allowed for detrimental monocultural practices such as lack of crop rotation--thereby necessitating use of fertilizers. Two (2) informants had a partial understanding that included adding a nutrient to the soil to make greener plants. Interestingly, two (2) informants held incompatible understandings, one (1) believed fertilizers were akin to steroids in humans and the other that they allowed plants to skip natural growth steps. The remaining informant had did not speak of fertilizers at all.

As with pesticides, informant experience with fertilizers seemed to promote a rich understanding. These experiences ranged from growing plants in a home garden to living in a rural environment. Additionally, the informant who had taken classes in agriculture was very discursive about the topic of fertilizers.

Courses taken in college also led to a rich understanding about the origin of winter lettuce. Six (6) informants understood that growth requirements of plants necessitated them being grown in geographic regions that provided suitable climates. Those that gave the most elaborate descriptions of this benchmark had taken a geography course where the topic of climate was addressed and lettuce was used as an example by the professor. Two (2) students held robust misconceptions about the origin of plant crops. They believed that crops came from the plain states even during the winter months. They did not consider plant growth requirements when they talked about the origin of the lettuce.

Informants were asked about the origin of the meat found on the burger. All stated that the cattle needed abundant land on which to graze. The speculated origin of the meat ranged from the western US to South America to Ohio.

The final benchmark dealt with how people obtained food when they were in unsuitable climates. All informants understood that food was shipped via trucks from where it was grown to places when it was ultimately consumed. Three (3) informants mentioned methods of transport other than trucks which were in accord with the expert conception for this benchmark.

III. Cultural-Historical

A. Social Change by Agriculture

The Cultural-Historical section examines one (1) key concept and one (1) benchmark corresponding to this concept. The key concept deals with human management of ecosystems and its benchmark focuses on how agriculture has changed society.

1. Effects of modern technology on farms, farmers and rural and urban communities.

Table 26 divides the benchmark *Explain the effects of modern technology on farms, farmers, and rural and urban communities* into three separate categories. Each is ascertained separately. The analysis proceeds alphabetically as the categories are found in the table.

Table 26. Prospective Teacher Understanding of: III. C. How has agriculture changed society?

Benchmark	Sid	Kat	Moll	Kara	Di	Dan	Guy	Meri
1) Explain the effects of modern technology on:	CE	CE	CS	CS	CE	CE	N	CE
a) farms, b) farmers and	CS	CE	CS	CE	CE	CE	N	CE
c) rural and urban communities.	CS	CS	N	CS	CS	CS	CS	CS

ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy; CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate

a. Farms

Sid, Kat, Di, Dan, and Meri were coded Compatible-Elaborate in their discourse about the effects of technologies on farms. Their responses included: 1) the increase in size of farms, 2) the decrease in number of farms, 3) the move toward specialization of crops produced, 4) the increasingly complexity of farms and the, 5) mechanization of farming operations. Molli and Kara held Compatible-Sketchy understandings because Molli mentioned neither the specialization nor the complexity of farms, while Kara mentioned the complexity, but not the specialization; this is to be expected as she thought that most farms produced many different crops (Benchmark I.A.1.). Further down the continuum, Guy was coded as Nonexistent because he was unable to articulate the effects modern technology had on farms. He knew that farms had become mechanized, but he said he did not know the impact.

b. Farmers

Relative to understanding technology's effect on farmers, Kat's, Molli's, Kara's, Dan's, and Meri's responses were Compatible-Elaborate when compared to the expert conception (Table 26). They understood that: 1) the number of farmers has decreased; 2) manual labor has been replaced by machines; and 3) farmers are increasingly dependent upon the technologies they employ. Sid mentioned the first two above, but did not articulate an understanding of dependence upon technology and was coded

Compatible-Sketchy. Guy said he did not know how technology affected farmers and was coded Nonexistent.

Meri's comments are representative of the informants' thoughts about technology's impact on farmers:

I- How about any machines that are used?

M- Tractors

I- OK, what can you tell me about that?

M- How they're advanced, how their, you don't have to go out and hoe it. I mean, they can go out there and in a few hours they can plow up the field. Their just advancing.

I- So then how has that impacted people?

M- The tractors. Well for farmers they can have mass production instead of, it's a lot less physical labor. I mean, you can go out and sit in your air conditioned tractor and listen to your favorite CD and plow the field.

c. Communities

No prospective teacher indicated a complete understanding of the expert conception relative to the impact of agricultural technologies on rural and urban communities. All--except Molli who was coded Nonexistent--articulated Compatible-Sketchy understandings of this benchmark component (Table 26). Kat, Di, Kara and Dan included four (4) of the five (5) ideas in their responses. They suggested that technology impacted society by: 1) promoting a shift in population from rural to urban areas, 2) shifting opportunities (employment, economic, etc.) from rural to urban centers, 3) allowing for the production of cheap food, and 4) altering cultural practices and social traditions with the move from an agrarian to an industrial society. Merri and Dan articulated the same propositions, with exclusion of cheap food, but added 5) mediating society's connection with the earth. Sid did not consider either the fourth or fifth propositions. Guy's understanding was even more sketchy and included only the notion that food would be cheaper as a result of technology. Molli, upon direct questioning about the impact on communities, did not proffer any ideas.

Dan's response to the probe about technology was very elaborate:

D- . . . the 1920s, we started to see urbanization in the US, a lot of industry--the automobile was starting to become a major factor--major player, especially from Michigan. [It] became more profitable for families to move into cities and off the farm to establish themselves and to live the American dream--to have things, to have a house, some of the finer things in life. Um, and those that did stay back on the farm started specializing and also, I believe, it was the 1920s when we started to really see a decrease in farm prices. It, that was the depression? I mean, correct me if I'm wrong, and um, it just wasn't profitable. It was more profitable to go into the cities and into industry--to skilled labor. Where, I don't mean to make farming sound like it's an unskilled profession, but at the time, building a car or cabinet--building furniture in Grand Rapids--were seen as skilled labor.

I- OK, some people moved because there were more opportunities, but then there were less people producing food, so what had to, what came in that allowed for this smaller number of people to produce food for an increasingly larger population?

D- Technological innovation--the farm tractor became a big key player, instead of having a team of horses and a one to two bottom plow, we now had the farm tractor and of course with that, the implements that could take care of the duties of harvesting crop, or planting a crops, so it wasn't, you know, wasn't a hand and shovel type job, you know, the farmer sat on a tractor and he did his work.

On the biological end at this time period, I think, you know, land grant universities became key players. Um, we were starting to look into scientific agriculture, you know, raising crops with a purpose, you know, there's a system for raising lettuce, you know, and farmers becomes more reliant on, you know, say places like Michigan State to give them advice and techniques to do their crops and manage their farms effectively.

Di also provides insight into a common line of thinking held by the prospective teachers:

I- Tell me a little bit about, on a broader picture, not just the farmer, but maybe on a societal impact, what would be the impact of things like that [new technologies].

D- I think it makes peoples' jobs easier, and it enables them to do more things, whereas they would spend more of their time doing that now they can use their time, like more and maybe do something else, like have another crop or another business or whatever, they're doing.

I- So you're still talking abut the farmer then?

D- Not necessarily, I mean, if it's a businessman who, like, sort of , any invention, gives you more time, you know, [its] kind of the purpose is to be more useful.

I- So, I'm still trying to figure out, so we have this irrigation that allows the farmer to irrigate in 5 hours verses 5 days and then you started to talk about business people. Tell me about that. How did you, there's a, you made a jump, but I'm wondering what's in the center of that jump.

D- I was just trying to expand it to society and I was thinking of other careers or other places where inventions are useful to people and I just thought of the business world. How they [technologies] enable things to go faster, sort of give you time.

Summary/Discussion

Generally speaking, informants were fairly well versed with the first two (2) benchmarks in this section. The majority of informants understood how modern technology affects farms by: 1) increasing their size, 2) decreasing their number, 3) specializing their crops produced, 4) increasing their complexity, and 5) mechanizing their operations. Likewise most said that technology affected farmers by: 1) decreasing their number, 2) replacing manual labor with machinery, and 3) increasing their dependency upon the technologies. Two (2) informants did not mention specialization and complexity in their responses to farms, while one (1) prospective teacher did not talk about farmers' increased dependency on technology. Additionally, one (1) informant in each of the two aforementioned benchmarks expressed no conception of technology's effect on farms and farmers.

Technology's effect on rural and urban communities was not as well understood. No informant's discourse matched perfectly the expert proposition for communities. The majority, however, understood four (4) of the five (5) goal conceptions. These conceptions were modern technology's effect on communities by: 1) promoting a shift in population from rural to urban areas, 2) shifting opportunities (employment, economic, etc.) from rural to urban centers, 3) allowing for the production of cheap food, 4) altering cultural practices and social traditions with the move from an agrarian to an industrial society and 5) mediating society's connection with the earth. The most often ignored was the last. Only two (2) prospective teachers mentioned how

technology disconnected the majority of society from nature. One (1) informant only mentioned increased food production as an effect of technology. Finally, one (1) informant did not possesses a schema to enable her to discuss how technology affected the farms, farmers, and rural and urban communities.

Findings from this group of benchmarks indicates that even though informants did not understanding the specifics of technologies--irrigation, fertilizers, etc. for example--the majority did understand how technology affected farms, farmers, and rural and urban communities (with the exclusion of one subconcept).

Prospective Elementary Teacher Benchmarks

The prospective teacher benchmarks are derived from the I. Science: Agricultural-Environmental Interdependence and II. Cultural-Historical key concepts aligned with two (2) key concepts. The first key concept is based on the role of science and technology in the agri-food system and the second with its impact on society. There is one (1) benchmark found under the first key concept and two (2) under the second.

I. Science: Agricultural-Environmental Interdependence

A. Role of Science and Technology in the Food and Fiber

1. Engineering of new varieties of farm plants and animals.

The first benchmark asked informants to describe how new varieties of farm plants and animals have been engineered to produce new characteristics (Table 27).

Table 27. Prospective Teacher Understanding of: I.A. What is the role of science and technology in the agri-food system?

Benchmark	Sid	Kat	Moll	Kara	Di	Dan	Guy	Meri
1) Describe how new varieties of farm plants and animals have been engineered to produce new characteristics.	CE	CE	N	CE	N	ø	N	CE

ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy; CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate

Sid, Kat, Kara and Meri--were coded Compatible-Elaborate--and understood that humans selected desired traits in farm plants and animals[2] and then employed strategies/technologies that would reproduce these valued characteristics. They mentioned reproductive techniques, such as selective breeding of seedstock, crossbreeding and hybridization, grafting in plants, and cloning. Interestingly, both Meri and Kat mentioned ethical concerns that cloning posed for them; Kat said it was "kinda God-like." Meri's conversation about cattle genetics displays her understanding of both selective breeding and cloning, while bringing to the fore her concern over cloning:

M- I know Angus beef is supposed to be the best.

[2] Questions related to the meat on the burger, because it was thought that informants would be most familiar with genetics in animals, specifically cattle.

I- Do you have any idea why?

M- Well their supposed to be corn fed. Um, they're supposed to have less fat in their meat. Just a better type of cow I guess. Probably genetically breeded to be better, to have less fat.

I- Can you tell me about that--how would they do that?

M- Well they probably pick the cows with the best traits and use those for breeding.

I- Can you think of anything else that maybe, any other technologies maybe that you've heard of that people might use now or possibly in the future to be raising and selecting?

M- Cloning.

I- Tell me about that.

M- I don't know--I think it's kind of weird. I mean, you're altering life.

I- What's cloning though?

M- Making the same identical thing over and over again, basically.

I- How would you do that?

M- Test tubes. Select the, chromosomes or what needs to be, you know, selected so that they can reproduce the same thing basically over and over again.

I- Why would they do that?

M- Well cause the one that they, you know, the one they're reproducing is probably the one they feel is the best cow--Angus beef.

I- OK, so they're going to produce the best one over and over again. Can you think of anything--so what's the advantage of that?

M- Well they would just--if you're getting the same thing over and over again--you don't have to worry about, you know, genetic defects if you 're going to be cloning--it won't be something that they're going to worry about

whether all their cattle were going to be this quality of meat that their putting on the label.

I- OK, can you think of any disadvantages?

M- Ya, you're altering human life, you're messing with something that I don't think that was probably meant to be altered or changed.

I- OK, so what about, why isn't it meant to be altered or changed? And you talked about human life or animal life?

M- Well most people don't think cloning is so bad because you don't really, I'm, if you clone a human, I'm, will it have the same personality, will it look exactly the same, are you making a twin? You know, it's not really a twin--it's a clone. It just seems [inaudible].

I- OK, let's go back. It sounds like you have a moral concern dealing with cloning of humans.

M- It seems kind of weird.

I- So let's go back to the livestock part. What's the disadvantage of that?

M- I don't, we haven't done too much with it. It could, you know, eventually, I don't know. It could eventually, you know, lead to something that we hadn't predicted.

On the other end of the understanding continuum were those with Nonexistent understandings--Molli, Di, and Guy. Guy and Di did mention that animals could be different from each other, but did not know *how* humans could perpetuate this differentiation with breeding schemes. Molli did not indicate that she had any understanding of the concepts listed in this benchmark. Di's discussion on the differences between dairy and beef cattle is noteworthy. She believes that there is a difference between these two types of cattle--and rightfully so--but she states she doesn't know how they got that way, or how they might stay that way. She doesn't see the connection between these animals and the humans who bred--and continue to design and breed--these beasts for the traits they value. Di states:

I- So, are there differences between the dairy ones and the meat ones [she was discussing dairy and beef cattle]?

S- I think so.

I- Tell me what you think.

S- I think that they are both capable of producing milk, but I think that the dairy cows produce more milk.

I- How?

S- I would think that just genetically. Like sort of a different line of cows.

I- So tell me a little bit more about that genetic thing.

S- I'm trying to think about what I can compare it to. I just think that there is sort of like a different breed of cow; I guess.

I- How did they get that way?

S- Um, I don't know. [Laughs], I don't know.

I- You talked a little bit, you said something about a line of cow, well, tell me about that.

S- Still the same sort of concept, like um, I'm not sure how they got that way, but I think.

I- How do they stay that way?

S- Well, I was under the impression that dairy cows, once you start milking them, that if you don't milk then, that they get sick, you know from keeping all that milk inside. So, I would think that once they are producing

> a lot of milk that they keep producing that amount and you need to, and that you need to, milk them [laughs].

Dan was labeled No Evidence, he was the first informant interviewed and I neglected to address this question specifically.

Summary/Discussion

There was a pronounced difference in understanding of how humans engineer new varieties of farm plants and animals. One group of prospective teachers--consisting of four (4)--understood that humans valued certain traits in plants and animals and then developed breeding methods to obtain these valued characteristics. They noted that humans employed selective and crossbreeding, grafting in plants, and cloning to mold nature into the desired image. Additionally, half of this group were troubled by the thought of cloning and broached ethical concerns.

Conversely, other prospective teachers--a group of three (3)--did not offer ideas of how new varieties of farm plants and animals came to being. Some knew that plants and animals had unique characteristics, but they did not know how they were derived or were perpetuated. One (1) student was not asked directly about this topic.

II. Historical-Cultural

Under the category Historical-Cultural there is one key concept: How has the modern agri-food system impacted society? and two benchmarks under this key concept dealing. They deal with the changes brought on by agricultural technology to: 1) the way people live and 2) work. An analysis of these benchmarks follows.

A. Impact of the Modern Agri-food System on Society

1. Agricultural technology has changed the way people live and work.

As Table 28 indicates, this benchmark was separated into its two parts, agricultural technology's affect on the way people: a) live and b) work.

Table 28. Prospective Teacher Understanding of: II.A. How has the modern agri-food system impacted society?

Benchmarks	Sid	Kat	Molli	Kara	Di	Dan	Guy	Meri
1) Explain how agricultural technology has changed the way people *live* and	CS	CS	N	CE	CS	CS	N	CS
work in the US over the last century.	CE	CE	N	CS	CE	CE	CE	CE
2) Describe trade-offs inherent in the use of agricultural technology in terms of: a) *environment* and	CS	CS	CS	CS	N	CS	CS	CS
b) human culture.	CS	CS	CS	CE	CS	CE	CS	CE

ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy; CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate

a. Live

On the first portion of the benchmark--live--only Kara vocalized all four (4) components of the expert conception and was coded Compatible-Elaborate. Her explanation included: 1) a shift of people from farms to cities, 2) a reduction of toil in producing and gathering food, 3) a disconnectedness from the land as a result of not growing food, and 4) an improvement in diet and health. In the passage below Kara discusses the changes that have resulted from technology. In particular she stresses how technology saves time, how it improves human health, and how it disconnects people from the production of food.

I Can you tell me about the types of technologies that have been used to produce food and tell me what their effects have been on people over the last 100 years?

K- Well the different types of technologies would be like as far as milking goes, I know that cows are hooked up to machines and they suck the milk, or, like they milk the cows from that and then they use it, those machines send the milk to whatever and they add vitamins, they heat it to get all the enzymes out and they separate. I know that they, it goes through a lot of different processes before it gets put into gallons or whatever. And that's good because it purifies it, but they put a lot of additives in it and some are good and some of them are bad. Like vitamin D milk, they had to put something in it to get it to be Vitamin D milk and skim milk, they had to take the fat out of it. So, it's a lot faster, and better for us, but I think we might rely on technology a lot. Like if that weren't the case, I think people would just cut milk and meat out of their diets a lot more, like we won't a lot of know how to do it without technology, so I don't know. It's good because you can do more, but it's bad because, like if that breaks down, then you can't, I mean you can get it fixed, but you might , I think they miss a lot too.

I- So let me go back, so you think there's less people farming now.

K- Yes.

I- So how has that affected people?

K- People don't appreciate, like don't appreciate what goes into it and like they complain about the prices, but don't stop to think about, like, ya know where you're getting it from. I mean, obviously, it is going to cost more if you're shipping it in from California or wherever and, um, they also don't stop to think . . . like what goes into it.

Sid, Kat, Di, Dan and Meri were coded Compatible Sketchy because they did not include all four (4) parts of the goal conception. Sid and Di excluded the disconnection from the land, while Dan and Meri also excluded one, the improved diet and health. Kat excluded both the disconnection and diet aspects.

Molli and Guy were Nonexistent as far as their understandings of the impact of technology on the lives of people. Guy doesn't seem to understand how technologies have impacted where people live over the past 100 years:

I- Has it [agricultural technology] affected people's lives?

G- The technologies? I can't, I don't think so, because to me, it's like, I guess they've always grown, I don't think so, because there's always been land set for growing vegetables and stuff, and raising cattle. I don't think that's pushed people away or drawn people.

b. Work

In the second part of this benchmark--changes in the way people work as a result of agricultural technologies--Sid, Kat, Di, Dan, Guy and Meri all stated the two (2) propositions defined in the expert conception: 1) the agri-food system is more mechanized and relies less on manual labor than during previous epochs, and 2) new employment patterns have emerged as a result of these innovations. They were coded Compatible-Elaborate. Interestingly, when Guy was not asked specifically about farms and farming, he was very discursive about the impact of technologies in other parts of the agri-food system.

Kara's response to this prompt was Compatible-Sketchy. Although she did acknowledge that labor requirements were reduced by technology, she did not speak to the changes in employment opportunities. Rather, her response focused exclusively on the on-farm implications of technological infusion.

Molli's response was coded Nonexistent. Like Kara, she had difficulty making a link between the use of agricultural technology and non-farm work. She seemed to be sorting out how industrialization has changed farming.

I- Can you tell me about what you think has changed in society's work in the last 100 years as a result of agricultural technology?

M- I think, I don't know, um, since the industrial revolution farmer definitely have just had to struggle because of that and there are more industrial farms than just family farms. People are having a hard time surviving in that.

I- Ok, and why?

M- It seems like more people are producing more food in factories. And ship them and sell them and do so much stuff like faster methods.

I- Can you tell me, you just said, um, make them in factories. What do you mean?

M- Um, I just think of like huge grain factories, or something and, that are breaking grain down or whatever you need to do, and turning into bread there, shipping stuff out from there, instead of just like a small family farm, being able to do that for ... amount of people.

2. Trade-offs of agricultural technology.

As with the previous prospective teacher benchmarks, the trade-offs in the use of agricultural technology were divided into its two parts: a) environment and b) human culture.

a. Environment

Table 28 indicates that all informants--with the exception of Di--articulated a Compatible-Sketchy understanding of the environmental aspect of the expert conception. The conception included: 1) altering the physical and biological world to maximize output of selected organisms (limiting diversity), 2) increasing changes of externalities of production by polluting the environment, and 3) promoting the use of an unsustainable agri-food system based on non-renewable resources.

Relative to the first component of the environmental expert conception, no informant, except Sid, mentioned the trade-off caused by selecting only the most immediately beneficial plants and animals for production. In the second part of this benchmark, everyone--except Di--knew of the trade-off of using technologies and polluting the environment. In fact, their responses were quite elaborate as evidenced by

Kara's response. She seemed to be aware of the trade-offs involved in the use of pesticides, but she was somewhat skeptical of their deleterious effects on her health.

I- You talked about, what are the positive things about pesticides and what are some of the trade-offs, some of the negative things about pesticides?

K- Positives are you get more crop. You harvest more, because I know a lot, some of the bugs will like eat you, I mean like, eat the whole thing. Like just ruin everything. Whether they lay eggs in it and make it their home, or whether they just eat in themselves; they'll ruin it. So that's a positive. I don't know but I want to say there's some kind of pesticide too, so that it can be kept longer, but I don't know that. The negatives are, they don't wash them off, like the producer, um, like the packer, might rinse the lettuce off, but I know they don't do a very thorough job of it, cause it's just like, I'm sure that it's just on a conveyer belt and they have water or whatever spraying on it and so it's not going to rinse all the pesticides off. And I know like lemons, they don't because there's a skin on lemons; they don't rinse those off. I have a friend who won't drink water with lemon in it at a restaurant because they don't wash the pesticides off the lemons. And I'm sure that part of it, but you know, like seeps into it, but you know, it affects it in some way. But, I mean, it's not harmful, because they, it's tested, so to a certain degree it might be harmful, but not anything that, like, you know, maybe if that was the only thing in your diet, you might.

I- So why would it be a big deal if there were pesticides on that lettuce or on that lemon?

K- Because they're pesti..., toxins. They're toxic and some people are just paranoid, like, if it doesn't kill it's all right, I guess, I mean, like you know, if I'm not getting , like you know, I'm not getting cancer from it or something like that, I'm OK, but um, some people are just real careful about what they put in their bodies, and I guess they rightly can be, but [inaudible].

I- Any other trade-offs?

K- I could see, because the pesticides, I know they do it, in, on a day that's not so windy, but because it's a pesticide it might get into the water, like

> because, it will be in the soil, so it might filter through, get in the water somehow.

In the last portion of the environmental trade-off benchmark, only Molli mentioned anything related to the lack of sustainability

> M- I think society has lost track of how things are done, or how things used to be, and the more technology that we develop, and the further advanced things become, the less people even pay attention, because they don't need to. They just assume it came from a farm and a farmer plowed it, grew it, whatever, and it came here--and I have it and that's all I worry about right now is that I have the food and that I'll eat it.

b. Human culture

Prospective teachers articulated a deeper understanding of the trade-offs of technology on human culture than for the environment. As indicated in Table 28, Kara, Dan and Merri were coded as Compatible-Elaborate because they stated that: 1) Agricultural technologies precipitated a reduction in the need for large numbers of people to produce food. As a result, cities swelled; additional time was available for other productive endeavors; population density increased; maladies of urban life came to the fore, 2) As a result of the previously mentioned shift, rural culture has declined and urbanites have lost a connection to the land and their food., and 3) Society has become increasingly dependent upon technologies for their economic base, while at the same time becoming fearful of risks that they no longer understand.

Sid, Molli, Kate, Di and Guy were Compatible-Sketchy. All indicated that humans had become dependent upon agricultural technology and that there were risks associated with their use. However they did not articulate an understanding of society's loss of rural culture and of city dwellers' disconnection from the land. Additionally, Molli did not speak of the time savings resultant from agricultural technology.

Summary/Discussion

Prospective teachers were reasonably well versed on the changes brought by agricultural technology to the way people live and work over the last century. Only one (1) informant, however, met the first part of this benchmark's goal conception entirely. She said technology had changed the way people live by: 1) shifting people from farms to cities, 2) reducing the toil of producing and gathering food, 3) disconnecting society from the land, and 4) improving diet and health. Five (5) other informants spoke of two (2) of these changes. The two (2) aspects of the goal conception were omitted by these five (5). They were: a disconnection of society from the land and the improvement of diet and health.

It seems that informants are unconscious of food's connection to the earth. This may be the result of their not being involved with the growing of the food. Additionally, they seemed to take for granted the high level of general health--brought in part by an abundant US food supply. This lack of understanding was further evident in two (2) informants who did not offer plausible explanations of changes to the way people lived as a result of agricultural technology.

Informants more clearly understood agricultural technology's changes on the way people have worked over the past century. Six (6) of the eight (8) prospective teachers spoke about the two (2) propositions found in the goal conception: 1) the agri-food system is more mechanized and relies less on manual labor than during previous epochs, and 2) new employment patterns have emerged as a result of these innovations. Additionally, one (1) informant spoke of the need for less labor as a result of agricultural technology, but did not expand this to include changes in societal employment patterns. Another did not articulate a full understanding of this concept. For the most part, prospective teachers seemed to grasp the ideas that the industrial revolution impacted society by making work easier. They, then, made connections between industrialization of society generally and changes in the agri-food system specifically--their schemas could accommodate the impact of agricultural technology on the way people lived and worked.

Trade-offs inherent in the use of agricultural technology in terms of environment were not as well understood by prospective teacher informants. There were three (3) components to the goal conception for the environment: 1) altering the physical and biological world to maximize output of selected organisms (limiting diversity), 2) increasing externalities of production by polluting the environment, and 3) promoting the use of an unsustainable agri-food system based on non-renewable resources. Although informants understood the immediate dangers of polluting the environment with pesticides and fossil fuel, only one (1) spoke of the loss of biodiversity that accompanies modern agricultural practices and only one (1) other addressed the lack of sustainability inherent in the current agri-food system. This lack of understanding of how society alters the environment through agricultural practices and then perpetuates a non-sustainable system through its food and fiber choices seems to be an area where education is most needed.

In the second portion of this benchmark (trade-offs of agricultural technology in terms of human culture) prospective teachers possessed a deeper understanding than they did for the environment. Three (3) informants understood all three (3) parts of the goal conception which included technological trade-offs in: 1) labor--resulting in a) less time required for food production and preparation, and b) increase in urban culture; 2) population shifts-- resulting in a) decline of rural culture and b) a disconnection from the land; and 3) dependency on machines and science--resulting in a) greater productivity, b) misunderstanding and c) fear. The other five (5)informants discussed the first and third components of the expert conception, but they did not address the decline of rural culture and society's general disconnection with the land.

Interestingly, the informants who grew up in rural areas demonstrated the most compatible and elaborate discourse relative to the cultural trades-offs inherent in the use of agricultural technology. The informants raised in urban areas were less balanced in their understanding and spoke more wearily of trade-offs resulting from agricultural technologies. Generally, as a group, they also spoke more often about the detrimental effects of these technologies than they did about the benefits.

Research Objective 4. Commonalties among informants within groups with regard to their backgrounds and experiences and to their understandings of the agri-food system.

To address the study's fourth objective, commonalties among informants with regard to background and experiences for both elementary and prospective teacher groups were assessed. The goal was to determine if associations between these variables were apparent. These variables included: demographic background and food and agriculturally-related experiences of informants. Findings for the elementary students are presented first followed by the findings for the prospective elementary teachers.

A. Elementary Student Informants

Analysis of these elementary student informants begins with the most general association and ends with the most specific. Three (3) commonalties surfaced. The first and most notable relationship is between understanding of the agri-food system and the background of informants. Overall, the suburban, European American, upper middle class SES group had the greatest number of Compatible-Elaborate (22) and the lowest number of Nonexistent (9) codings of the three groups, while the urban, African American, lower SES group had the lowest number of Compatible-Elaborate (14) and the highest number of Nonexistent (16) codings.

The second commonality dealt with understandings of specific benchmarks by groups. Groups of informants displayed marked differences related to their understanding of the science benchmarks in two areas: 1) pests and pesticides and 2) origins of food. The European American, upper middle class SES group members were the only informants to describe weeds as pests that farmers might need to protect crops against. Two informants from this group--Tim and Ema--explained that the weeds would compete for growth requirements--specifically light and water--with other, more desirable plants. Ema explained that crops are lost to weeds because they competed with crops for space and for growth requirements.

I- Can you tell me, you talked about plants growing and blocking out something, tell me about that.

E- Yeah, there might be other weeds or plants or something that are growing too close and the leaves might block out the sunlight from the lettuce and make it die, because it doesn't get much sunlight.

I- So what would the person who is growing the lettuce do?

E- Probably chop down the weeds or before they grow the plants, if it's like has another vegetable a little farther.

I- So they have more space.

E- Yeah.

Conversely, urban Detroit informants who had never gardened had no schema related to pests. They did not express any understanding of: 1) how pests (insects or weeds) affect crops, 2) how crops might be protected from pests, or 3) the positive and negative impacts of using pesticides.

A similar pattern held true for understandings related to the origin of food. The suburban informants were better able to identify and explain why crops were grown in specific geographic locations. Four (4) of the six (6) urban students (Jay, Jill, Mona, and Sara) were unable to identify the locations where crops may have logically been grown in winter months; it seemed they had never considered climate before. Jay, Mona and Sara, when asked about the origin of the lettuce all gave answers similar to Sara's "out in Michigan" or Jay's "here or in Detroit." Jay's comments are typical of this group of students:

I: Now the lettuce and the pickles, where do you think they were grown?

J: ...Probably grown, here.

I: So, what was the temperature like here in Michigan last month?

J: Cold.

I: So, go ahead.

J: About in the...fifties [it was actually about 30 degrees F].

I: OK, how do you think lettuce would grow in the fifties?

J: Not very good.

I: So, you still think it was grown here in Michigan?

J: (Shakes head) No.

I: Where do you think it was grown then?

J: Probably out in Detroit.

This group of informants did not take the knowledge of plant growth requirements in benchmarks II.A.1. regarding the need for specific climates for growth and II.B.1. regarding basic plant growth needs and link it to Michigan winter weather conditions or the use of the transportation systems elaborated upon in benchmark II.C.3.--obtaining food from more suitable climates.

The final commonality was found in Mona's and Sara's understandings (urban Detroit females who had not grown food). Both informants had little experience with food before it got to their table. They elaborated upon the unhealthfulness of food and detailed the changes in the agri-food system that made food of lesser quality and wholesomeness than in the past. They both said that the newspapers, television and their families were the sources of their understandings. Sara explained:

S- Foods are, I heard on the news, sometimes how food can damage you or . . .

I- Tell me about that.

S- Ok. I heard on the news sometimes that when you get, they tell you be careful, because what kinds of foods that they have, or um tooth pastes, or anti-biotics, um, how that can hurt you or make you sick.

I- How? How does it do that?

S- I think it's, well it's my opinion. I think sometimes there is probably some stuff that is in it. And then they put extra stuff in it or something and it makes sick. It probably . . .

I- Like what extra stuff? Like for food. What extra stuff for food to put in?

S- They put lots of chemicals.

I- Like what?

S- Like, orange juice.

I- Tell me about that.

S- Ok. Orange juice is now hot like it really used to was.

I- How is it different?

S- Because they put, it is not like real orange juice, it's not like real orange, because they put stuff in it that makes it taste, um, like, like orange juice.

I- Ok. So artificial stuff is put in?

S- Yeah. Makes it seem like orange juice, just like orange juice or milk.

I- Right. Tell me about that.

S- Milk is not like it was like back then, because they put some chemicals in it to make it taste like milk, just like orange juice.

I- Ok. Why do they do that?

S- Probably they don't like, probably most people have opinions like they don't like real milk or real orange juice probably. So they wanna put something in it to make it taste better.

B Prospective Teachers

Just as in the previous section, a broad view of the commonalties or apparent associations are presented, followed by a more detailed analysis. This group of informants was not purposefully selected other than by the fact that they all were prospective elementary teachers. As it happened, however, there were three (3)

informants who were raised in rural Michigan. These three (3) students--Dan, Meri, and Kara--were the most knowledgeable about the agri-food system. They were coded the most often in the elementary (K-5) benchmarks as Compatible-Elaborate (CE), with 12, 11 and 10 times respectively. Additionally, Meri and Kara were also tied for the most number of CE codes in the prospective teacher benchmarks (Dan scored two (2) CEs in this category and one (1) No evidence, because of my error at the beginning of this study). These informants were not coded "Nonexistent" for any of the benchmarks. It must be restated that Dan's minor was in agriscience and Kara's father was a farmer; therefore, it would be ill-advised to argue that only geography played a role in these three (3) students' deeper understanding of the agri-food system than their contemporaries.

As with the elementary informant group, literacy--as measured by coding on the benchmarks in this study--was lower in the prospective teacher group who had no experience with gardening and who was raised in urban Detroit. Molli and Guy, who both had never gardened, were coded with the least CEs for the elementary benchmarks. Guy had six (6) and Molli four (4). They also had the largest number of CI, IS, IE and N codings of the prospective teacher informants. Similarly, Molli (3) and Guy (2) were coded with the most Nonexistent for the prospective teacher benchmarks. Di--who also was reared in Detroit--had two (2) Ns as well.

Upon deeper analysis, it became apparent that Molli, Di and Guy were coded similarly on their understanding of fertilizers. Both Dan and Molli held misconceptions about what fertilizers do to crops. As stated previously, Guy believed fertilizers to be akin to human steroids, while Molli believed that fertilizers cause plants to skip natural processes. Her ideas about fertilizers included:

I- You talked about fertilizers and chemicals, tell me how those would be used on this farm.

M- Probably use just to make a lot of it if they are trying to sell it.

I- And what does it do?

M- I don't know, like probably just something to speed up the growth process of whatever crop they would be growing.

I - And what would it then be supplying to the plant that is going to speed up the growth process?

M- What do you mean?

I- Well, you're saying that their giving it fertilizer so that it speeds up the growth process, so this is a plant, right. Lettuce is a plant, what is it doing?

M- What is the fertilizer doing? I don't know, some kind of chemical that would probably just like, not go through the natural steps of growing, or maybe do it but somehow, I don't know how, but somehow makes it go faster, maybe miss steps that it won't go through natural growth, or something.

At the other end of the fertilizer knowledge and understanding was again--Dan, Kara, and Molli. They had well-developed schemas for fertilizers that allowed them to talk at length about such ideas as organic and inorganic compounds, pumping organic matter into the soil via cover crops, etc. Their understandings were enriched by personal experience that they conveyed through their discourse.

Of additional interest was the commonality held by Meri and Guy. Guy, whose overall agri-food system literacy was low in comparison to his contemporaries, held the most compatible and elaborate understanding related to the origin of the lettuce. Guy had taken a geography course at Michigan State University in his social studies minor. Meri, also a social studies minor, took the same course. They both held extremely deep and well reasoned notions as to why most lettuce in the US comes from California. They also, reported that this class contributed to their understanding of the monocultural nature of most farms in the US. Their understandings of the role climate plays in determining where crops can be grown was also influenced by this educational intervention.

Summary/Discussion

In sum, it seems apparent that there were commonalties among informants in both groups. In the elementary group, high SES, gardening and not living in an urban environment were correlates that manifested in a more compatible and elaborate understanding of this study's benchmarks. Specifically, students from suburban, gardening, high SES held a richer understanding of pests and pesticides than did the urban, non-gardening, low SES students. Similarly, these groups differed in their understanding about the origin of winter produce. Urban, non-gardening students seemed to lack a schema for both these clusters of benchmarks. One might speculate that this results from their lack of experiences with growing food and from a dearth of opportunities to travel and gain a more broad geographic perspective.

The prospective teacher group bore similar trends as the elementary students. Informants who gardened and were raised in rural areas achieved the highest attainment of the agri-food system benchmarks, while non-gardening suburban and urban informants were lowest. This was most apparent in the benchmark that dealt with fertilizers where the rural gardening students were markedly higher than those who did not garden. Of additional interest is the commonality of understanding promoted through a college course. Two (2) students who both completed a geography course held the most compatible and elaborate understanding for the how climate relates to the origin of food. This suggests that much of the lack of understanding about the agri-food system could be ameliorated by education.

Research Objective 5. Differences between prospective teachers and students relative to their understandings of the agri-food system.

This research objective addresses the differences found in the elementary student and prospective teacher groups. It must first be stated that what is most striking about these two groups is the many similarities. Notable differences are found in three (3) of the eighteen (18) or twenty-three percent (17%) of the elementary benchmarks and their subcomponents. These benchmarks were:

I.A.4. Describe how agriculture uses natural resources to provide peoples' basic needs.

II.C.1. Explain why irrigation and fertilizers are used to grow crops.

III.A.1 Explain the effects of modern technology of farms, farmers, and rural and urban communities.

Differences were identified by comparing codes of the two groups--a description of the decision criterion for selecting notable differences can be found in Chapter 3. The findings for this question begin with the benchmark from the I. Agri-food system standard, then address the II. Science: Agricultural-Environmental Interdependence benchmarks, and conclude with the III. Historical-Cultural benchmarks.

A. Agriculture Uses Natural Resources

The first benchmark where differences were noted between the elementary student and prospective teacher informants was *I.A.4. Describe how agriculture uses natural resources to provide peoples' basic needs*. This was the only benchmark where elementary students held more compatible and elaborate responses than did the older and more educated prospective teacher group. The major difference laid in three elementary students' understanding that air was a natural resource needed by plants to live. None of the prospective teachers ever mentioned air as a natural resource or basic need for plants.

B. Irrigation and Fertilizers

The second benchmark where differences were noticed was *II.C.1. Explain why 1) irrigation and 2) fertilizers are used to grow crops.* This benchmark was divided into two parts: a) irrigation and b) fertilizers.

1. Irrigation.

In the case of irrigation, elementary students understood--on a basic level--that crops needed a constant supply of water for growth, but did not expand beyond this fact. No informant used the word irrigation during the interview. Students did not bring up the fact that humans grow crops in regions unsuitable for unaided plant growth (arid or desert climates). The majority of teachers, on the other hand, understood the connection between water requirements and where humans grow crops. To make this connection, teachers synthesized what they knew about these two ideas and reasoned why there was a connection--something none of the elementary students articulated orally.

2. Fertilizers.

Only two (2) elementary student informants discussed fertilizers, the other seven (7) never mentioned fertilizers (or any kind of plant growth promoter)--only one elementary informant explicitly used the word fertilizer. These two (2) informants understood that a substance could be given to plants to promote growth. They did not, however, link this idea to increased crop yield and a major reason why fertilizers are used-- modern monocultural practices.

In contrast, three (3) of the prospective teachers had a compatible and elaborate understanding of why fertilizers were used, while the conceptions of another two (2) were murky. The CE informants made explicit links to the results humans gleaned from fertilizers and the reason why they are used. Again, as in the irrigation sub-concept, selected teachers were able to connect knowledge structures to form a schema for fertilizer use.

Of the remaining three informants not yet described, two (2) held misconceptions and told inaccurate stories about fertilizers--the last held no conception about this topic. The sub-benchmark fertilizers, then, is an area flagged by meeting the criterion for difference, but is not one where clear understandings are present for only a few prospective teachers. This finding is of particular import, as both agricultural and science educators suggest that elementary students should grasp this concept.

C. Effects of Modern Technology on Farms, Farmers, and Rural and Urban Communities

The final benchmark that met the decision criterion, and the one where the greatest difference was found, was *III.A.1 Explain the effects of modern technology on*

farms, farmers, and rural and urban communities. This benchmark was divided into three (3) sub-components: a) farms, b) and c) communities.

1. Farms

In the first sub-component, students generally understood that farms were mechanized, but they did not make a connection between mechanization and the effects it had on farm size, complexity or number. The majority of prospective teachers, conversely, held schemas that allowed them to articulate the cause-effect relationship between technological use and farms.

2. Farmers

Closely akin to the understandings informants' held regarding farms was the effect technology had on farmers. As a group elementary student informants were less aware of the effects technology had on farmers than the prospective teachers. The majority understood that technology reduced labor requirements, however only two (2) made a link between technology and a reduction in the number of farmers, and their dependence upon technology. Only one (1) elementary student informant held a Nonexistent understanding of technology's affect on farmers. Interestingly, most elementary students--when first asked about technology--talked about computers.

Similar to the other technologically-based sub-components, the majority of teachers held richer schemas than the elementary students that allowed them to evaluate the affects of technological innovations on farmers, lives and businesses. Those teachers that did not possess schemas that allowed for compatible and elaborate discourse about this topic sounded amazingly like the elementary student informants.

3. Communities

No elementary student informant articulated a clear understanding of the effects of technology on communities. The majority understood that food production was higher when using technology, but were unable to specify how technology further affected rural and urban communities. They were unable to make the abstraction on a broader scale that most of their prospective teachers made. The prospective teachers articulated a piecemeal understanding of the expert conception which included the following effects: 1) a shift in population, 2) the creation of new opportunities, 3) the loss and creation of culture, and 4) a move toward increased alienation from the land. It must be mentioned that seven (7) of the eight (8) prospective teacher informants were coded Compatible-Sketchy.

Summary and Discussion

Notable differences were found between teachers and students in 17% of the benchmarks and their subcomponents. Generally speaking, the differences between elementary student and prospective teachers lay in the connections they made within their idiosyncratic schemas. Specific differences were found in three (3) areas: 1) natural resources use in agriculture, 2) irrigation and fertilizers, 3) the effects of technology on farms, farmers and communities.

In agriculture's use of natural resources, the difference was found in selected elementary students understanding that air was a natural resource that was required by both plants and animals. No prospective teacher mentioned air during their interview. This could be the result of students recently learning this fact in science class.

The second area where differences surfaced was in the irrigation and fertilizer benchmark. Although elementary students understood that plants required water to live, they did not discuss why humans needed to irrigate crops. Prospective teachers, on the other hand, said that humans grew crops in areas that were warm, but that also lacked precipitation. Similarly, more prospective teachers were aware of what fertilizers were and why they were used than were elementary students. Most students, like some teachers, did not understand that fertilizers supplied minerals to plants.

The last benchmark where differences were manifest dealt with the effects of technology on farms, farmer and communities. The major difference between students and prospective teachers was in the ability to make cause-effect type evaluations. Elementary students knew that farmers used more machines that increase food production, but were generally unable to make the leap to judge the consequences of this technology for the farmers' lives, the structure and number of farms or the culture and make-up of communities. The majority of prospective teachers, themselves, did not have a clear understanding of the effects, but were more compatible and elaborate with the goal conception.

CHAPTER 5

CONCLUSIONS / IMPLICATIONS

Overview

In Chapter Four, the findings of the study were presented and discussed. Chapter Five begins with a summary of the findings. This is followed by conclusions/discussions that are drawn from those findings. The conclusions are divided between the two dimensions of the study's theoretical framework: psychology of learning and sociology. In the final section of the chapter, implications for educational research, curriculum development, collaboration and teacher preparation are offered.

A. Summary of Findings.

A summary of findings is presented below for each research objective. The first, fourth, and fifth objectives are presented in a narrative, while the second and third are summarized in Tables 29, 30 and 31. because of the extent of the findings related to these two objectives.

1. Research Objective 1. Informants' backgrounds and experiences.

The elementary student informants for this study were five (5) females and four (4) males. They were of European or African ancestry and came from urban and suburban backgrounds. Student informants attended both parochial and public schools. The parent occupations for this group ran the gamut from janitor to pharmacist. The informants were evenly divided by socio-economic status (SES) groups: lower, lower-middle, and upper-middle. One of the students who lived in a urban location had once lived in rural areas in the western US.

The prospective teacher backgrounds were less varied than those of the student informants. There were eight (8) informants in this category, three (3) were male and five (5) were female. All of them were of European ancestry--all were white. Two (2) attended Catholic school, and the remaining six (6) attended public school before college. All informants attended Michigan State University and majored in elementary education. Prospective teachers came from urban, suburban and rural backgrounds. Occupations of their parents varied from janitor to landscape architect.

All informants in both groups had food-based experiences. The primary difference among them was experience with gardening. Two (2) informants in each group, for a total of four (4), had never grown food. Of these, three (3) were raised in Detroit ,and the other in one of its suburbs. Additionally, two (2) prospective teachers had experiences working on farms.

2. Research objective 2. Elementary students' understandings of the agri-food system goal conceptions.

The next objective sought elementary student understanding of goal conceptions for agri-food system literacy. The sophistication of informant thinking about a given topic was judged for each subconcept along two dimensions: quality (compatibility) and depth (elaboration of response) by comparison with expert conceptions. Student understandings were assigned codes based upon this comparison scheme (Table 12).

Table 29 lists key concepts and benchmarks in the left-hand column. Included in the right are the most common codings as well as codings that are of particular import because they are indicative of trends found within the data. Comments are provided next to the codings to illuminate salient findings embedded in the data.

Table 29. Elementary Student Codes for Goal Benchmarks

Key Concept/Benchmarks	Codings/ Comments
I.A. Agriculture 1) Products from plants and animals.	CE - plants and animals as the source of food
2) Variety of farms.	CE - food comes from farms CS- farms look like big gardens CS- farms are big-4 football fields in size
3) Journey of food or fiber.	CE- network of interrelated systems
4) Agriculture uses natural resources.	CS- lack of air as a requirement
II.A. Ecosystem Management 1) Crops depend on climate and soil.	CE- climate-(temperature and precipitation) required for growth in regions CS- soil-needed for growth, "good" but no idea of what makes it good
II.B. Management of Crops 1) Basic growth requirements	CS- animals and plants-missing space and air, little idea of what requirements do
2) Crop loss to pests.	CS-animal pests (insects rodents, etc.) CE-weeds compete for growth requirements - suburban informants only N-weeds-urban students
3) Crop protection from pests.	CS- dependent on type of pests known, see

	benchmark II.B.2 above
4) Impacts poisons to protect crops.	CS-those that knew of insects (benchmark II.B.2) mentioned pesticides impacts N-no schema for non-insect knowers
II.C. Science and Technology 1) Irrigation and fertilizers.	irrigation: CS-knew plants needed water, but no link to humans choosing to grow in arid regions fertilizers: N-majority of informants CS-stuff to make plants grow IE-food for plants
2) Origin of common foods.	CE-interplay of climate, growth requirements, and geography N-no link to climate and geography, urban students
3) Food is from suitable climates.	CE-food is transported via trucks
III.A. Agriculture Changed Society 1) Effects technology.	CS-mechanization decreases labor, but no link to number of farmers or farmers; cause-effect relationships missing N- no knowledge of affects on communities

ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy; CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate

3. Research objective 3. Prospective elementary teachers' understandings of the agri-food system goal conceptions.

The third objective sought prospective elementary teacher understandings of goal conceptions for agri-food system literacy. The same procedures for coding were followed as described previously for the elementary student informants, except that additional benchmarks exclusively for prospective teachers were also coded. Tables 30 and Table 31 list key concepts and benchmarks in the left-hand column. Included in the right-hand column are the most common codings as well as codings of particular import because they

describe trends within the data. Comments are provided next to the codings to illuminate salient findings embedded in the data.

Table 30. Prospective Teacher Coding for Elementary Benchmarks

Key Concept/Benchmarks	Codings/ Comments
I.A. Agriculture 1) Products from plants and animals.	 CE - plants and animals as the source of food
2) Variety of farms.	CE - food comes from farms CS- farms look like big gardens CS- big farms - 2-20+ football fields in size
3) Journey of food or fiber.	CE- network of interrelated systems
4) Agriculture uses natural resources.	I- lack of air as a requirement
II.A. Ecosystem Management 1) Crops depend on climate and soil.	CE- climate-(temperature and precipitation) required for growth in regions soil: CE- only rural informants CS- needed for growth, but no idea of what it supplies
II.B. Management of Crops 1) Basic growth requirements	CS- animals and plants-missing space and air, little idea of what requirements do (sun, water, soil)
2) Crops loss to pests.	CE- animal pests (insects, rodents, etc.) CE- weeds-rural informants N- weeds urban students
3) Crops protection from pests.	CE- rural informants CS- pesticides only, most informants
4) Impacts poisons to protect crops.	CS- negatives better understood than positives
II.C. Science and Technology 1) Irrigation and fertilizers.	CE-irrigation needs of plant and where grown fertilizers: CE- rural informants CS- gave something to plant to make it greener IE- steroids for plants
2) Origin of common foods.	CE- climate, geography, and growth needs IE- plains states where the farms are
3) Food comes from suitable climates.	C- food transported via trucks
III.A. Agriculture Changed Society 1) Affects technology.	CE- farms and farmers, mechanization CS- mechanization, incomplete on affects communities

ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy; CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate

Table 31. Prospective Teacher Codings for Teacher Benchmarks

Key Concept/Benchmarks	Codings/ Comments
II.C. Science and Technology 1) Engineering of plants and animals.	CE- human design animals and plants N- no idea
III.A. Agriculture Changed Society 1) Technology's changes-live and work.	live: CS- missing food's connection to land and improved health and diet work: CE: deep understanding of industrialization and changes with work
2) Trade-offs of agricultural technology.	CS- understood pollution, but lack understanding of loss of biodiversity and sustainability

ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy; CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate

4. Research Objective 4. Commonalties among informants within groups with regard to their backgrounds and experiences and to their understandings of the agri-food system.

The fourth research objective probed commonalties within informant groups in regard to understandings of the agri-food system benchmarks. In the elementary group, high SES, gardening and not living in an urban environment were correlates with the most compatibility and elaboration of understanding the study's benchmarks. Specifically, high SES students held a richer understandings of pests and pesticides and the origin of winter produce than did the urban, non-gardening, low SES students. Urban, non-gardening students seemed to lack a schema for both these benchmark clusters.

The prospective teacher group exhibited trends similar to those among elementary students. Informants who gardened and were raised in rural areas achieved the greatest understanding of the agri-food system benchmarks, while non-gardening suburban and urban informants demonstrated the least understanding. Additionally, enrollment in a college geography course appeared to improve understanding of the origin of food in relation to climate.

5. Research Objective 5. Differences between prospective teachers and students relative to their understandings of the agri-food system.

In the final research objective sought differences between groups in regard to agri-food system understandings. Notable differences were found between teachers and students in 17% of the elementary benchmarks and their subcomponents. Generally speaking, the differences between elementary student and prospective teacher groups were in the connections made between knowledge structures to proffer casual relationships. Specific differences were found in three (3) areas. In the first, several elementary students added air as a resource needed by plants and animals, while no prospective teacher did.

The second area dealt with irrigation and fertilizers. Prospective teachers related warm, arid climates chosen by humans to grow food to the need for irrigation; younger learner did not make a connection between human placement of crops and the need for water. Additionally, more prospective teachers were aware of what fertilizers were and why they were used than were elementary students.

In the final benchmark, effects of technology on farms, farmers and communities, the major difference between students and prospective teachers was in the ability to make cause-effect type evaluations. Elementary students were generally unable to make the leap to judge the consequences of technology for farmers' lives, the structure and number of farms, or the culture and composition of communities. The majority of prospective teachers, themselves, did not have a clear understanding of the effects, but were more compatible and elaborate with the goal conception.

B. Conclusions/Discussion

The study's conclusions are organized around its theoretical frameworks in psychology and sociology. Conclusions are presented first which aligned with teaching and learning theory with particular emphasis on agricultural and science education. After these conclusions are presented, a broader perspective is discussed that links the findings of this study to society.

1. Conclusion from a Teaching and Learning Perspective.

This study's conceptual framework used conceptual change theory as a foundation in the study of the agri-food system. A review of the literature indicated this research methodology had never previously been employed in agricultural education to assess agri-food system understandings. This study shows that conceptual change research methods can be fruitful in surfacing informant conceptions in agricultural education. Tables 29, 30 and 31 indicate that informants generally held conceptions classified as compatible (CE and CS), incompatible (IE and IS), and nonexistent (N). CE conceptions were primarily found in benchmarks of a factual nature, such as plants and animals being the source of food, food's origination at farms, etc. In both elementary student and prospective teacher groups, the CS coding was the most common. This indicates that informants held partial understandings of agri-food system concepts. These incomplete understandings were often found in concepts that required informants to make connections between biological, physical, and earth science concepts. Informants had difficulty with connecting to schemata that could help them fully explain concepts orally.

The third most often assigned code was Nonexistent, indicating that informants were not able to access cognitive structures related to the agri-food system to make sense of the interview prompts. Interestingly, informants with nonexistent understandings may prosper the most from direct instruction. Hogan and Fishkeller (1996) found that learners who held non-conceptions learned more than those who held compatible but sketchy and incompatible understandings on the topic of nutrient cycling in ecosystems. It is also noteworthy that the incompatible codings were the least assigned in this study, because they show that few of the agri-food system concepts are deeply rooted within the schema of most informants. Time consuming educational interventions designed to reconstruct misconceptions can be kept to minimum, because the schemata are not burdened with misconceptions, rather the accurate conceptions are simply not present.

The second part of the study's psychological focus included sociocultural theory. The theory was well supported by the findings of this study. Findings in both groups indicated that experiences outside of school were the strongest determinant of agri-food system literacy. This is supported by the fact that informants who held the understandings most compatible with expert conceptions, time and again, related their discourse to personal experiences and not school-based learning (except in reference to plant and animal growth requirements, natural resources, and climate). These experiences were most apparent in the student understandings related to: pests, crop protection, pesticides, fertilizers, irrigation and the origin of foods. Informants from both groups with background in gardening or who had traveled outside of an urban area conveyed much richer, more scientifically accurate discourse than students from urban areas who had not had these experiences. Codings of the urban non-gardening informants present a clear pattern of limited understanding for both the elementary student and prospective teacher groups.

Of further interest is the link between younger informants and their families in regard to learning about the agri-food system. Findings indicate that parents and grandparents were instrumental in providing younger children with knowledge that was integrated into their schemata. Informants from urban areas referred to listening to parents talk about the higher quality of food in past generations. From these experiences, they developed a mistrust of food makers and misconceptions about the composition of food products. On the other hand, students who gardened with their parents or assisted with maintaining lawns were more likely to understand the linkages between in-school and

out-of-school learning. It appears, then, that most learning about the agri-food system occurs through informal activities with families and not in school.

Similarly, prospective teacher informants who were raised in rural areas, as a group, held the most (C) and least (N) codings. Therefore, one can cautiously link the experiences gleaned in these settings to the development of ideas and schemata that helped them to understand the agri-food system.

This study also surfaced polarities in terms of prospective teacher understandings of higher level conceptions (high school benchmarks called prospective teacher objectives in this study). Over a third of these university juniors and seniors were unable to talk about how farm plants and animals are engineered by humans to produce specific traits. Even though they most likely were required to take a biology course in either high school or in college, they were unable to offer any ideas about human designed life forms to obtain the things they value. As biotechnology increasingly enters public discourse, it is alarming that a significant number of future teachers in this study possessed such limited understanding of even rudimentary applied genetics.

This study also brought to the fore limited understanding of the trade-offs inherent in the use of agricultural technology in terms of the environment. Future teachers understood that agricultural technology could increase crop yield while at the same time contribute to environmental degradation through pollution from fossil fuels and improper use of pesticides. However, only two (2) of these informants mentioned ecosystem decline over a long time horizon. Specifically, college students did not understand how current farming practices alter the environment and necessitate the reduction of biodiversity. This lack of understanding of how society alters the environment through agricultural practices and then perpetuates a non-sustainable system through its food and fiber choices seems to be an area where the need for education is most evident.

2. Conclusions from a Societal Perspective

Although the need for education about the environmental-agri-food system connection was apparent from the findings of this study, it will be a difficult topic to arouse a need for in society's consciousness. Humans are confronted with thousands of choices and decisions daily. In order to deal with the complexity of the world around them they develop a bounded rationality (Simon, 1978). By bounding rationality to a limited number of decision sets, one is able to live in the complicated and changing world. Bringing new rationalities to consciousness (e.g., the link between food and fiber choices and environmental degradation) will be exceedingly difficult, at best. People simply do not have the capacity--nor energy--to understand and care about all things. As a result, they concern themselves with issues that affect them personally--and for many the complexities and trade-offs of the agri-food system are far removed and inconsequential.

As this study has shown, the hegemony (Feenburg 1995) of science and technology in the agri-food system is well entrenched. Students learn about the canons of science with little ability to make links to real-world application in their own lives. They learn about the effects of industrialization of the 19th and 20th centuries--as evident by the extensive discourse of informants about the industrial revolution--but are blinded, by bounded rationality, to the trade-offs inherent within their own epoch. This may be because of misconceptions and non-conceptions held by most people about the agri-food system. For example, this study found that the majority of elementary and university students believed a farm today looked like a large gardens-a picture from Grant Wood's "American Gothic." They held conceptions of farms that were not compatible with today's reality.

These non-and misconceptions of scientific principles and technological realities serve to limit understanding of the agri-food system. As such, they limit society's ability to see how its choices influence human health and safety and environmental sustainability for future generations. Democratic participation, an ideal of liberal democratic theory, is based upon a citizenry that has the ability to make informed decisions. This study has shown that most elementary students and prospective teachers do not possess the ability to draw upon scientific concepts to engage in democratic discourse about environmental trade-offs in the application of agri-food system technologies. Feyerabend (1978) comments on democracy and the need for learning that is relevant for active participation in decisions of the day:

> a democracy is an assembly of mature people and not a collection of sheep guided by a small clique of know-it-alls. Maturity is not found lying about in the streets, it must be learned. It is not learned in schools, at least not in the schools of today where the student is confronted with desiccated and falsified *copies of past decisions*, it is learned by active participation in decisions that are still to be made (p 87).

Feyerabend's critique of formalized schooling merits consideration in light of this study's findings that out-of-school experiences were the strongest determinant of an informant's ability to engage in discourse about the agri-food system's effects on society and the environment.

C. Implications of Study

Implications from this study follow. First to be presented are implications that highlight research agendas and study that are logical extensions of this study. Next recommendations for curriculum development are offered. This is followed by discussion of how identifying developmental ideas and collaborating in agricultural and science education can promote agri-food system literacy. The last implications are proffered for creation of an interdisciplinary approach to teacher education about agriculture.

1. Research

First, further research can yield deeper understandings of what people know about the agri-food system. Specifically, additional use of this study's research protocol by other researcher on similar, but different groups, for example, can add to the generalizability of findings. These studies might target areas where non-and misconceptions are present. With misconceptions, researchers may consider determining the robustness and cause of inaccurate schemata. Additionally, there would be profit in studying groups that are: a) are less educated and b) are in elite policy making positions. This range would yield further understandings of what others in society comprehend about the agri-food system. Finally, researchers may consider utilizing quantitative methods to determine if the findings from qualitative studies of small groups can be generalized to a large population.

2. Curriculum Development

This study has implications for those interested in curriculum development. Findings from this study shed light on the understandings found in elementary and college students. For those developing curriculum and other educational interventions, this study provides a glimpse of what conceptions these two groups do and do not hold.

Specifically, designers of elementary curriculum do not need to focus on food's origin from plants and animals; students already know the biological origin of their food. On the other hand, curriculum that helps students understand the structure and size of modern farms could be fruitful in confronting misconceptions about farms looking like large gardens.

In the area of Ecosystems Management, science educators might further concentrate on helping students develop an understanding of soil's contribution of minerals to plants. By teachers integrating fertilizer laboratory activities into the teaching of plant growth needs, both soil nutrients and the contributions of fertilizers could be fused into a connected whole. Likewise, curriculum designers could "double-dip" by using the agricultural example of crop pests to provide a context for learning about competition among living things. This would be of particular import because the majority of elementary students in this study did not have any conception of how weeds compete with crops for sun, soil nutrients, space and water. Curriculum based on school gardens could be illustrative of competition. In these gardens, students could also weigh--under the supervision of an experienced teacher--the pros and cons of pesticide use, which is another area where students held incomplete understandings. Finally, elementary curriculum designers may consider linking the idea of industrialization to present day agriculture. Students spoke at length about industrialization as it relates to past epochs, but few used examples of the technologies of the present. Specifically, elementary students thought of technology only in terms of computers and machines; they did not extend technology to the biological realm. This is noteworthy because agriculture is now on the cusp of a revolution based on biotechnology, and society will increasingly be confronted with the risks and benefits of these innovations.

This study underscores the need for an enhanced curriculum for prospective teachers. Like the elementary students, one-half of these college students did not understand about the engineering of plants and animals by humans. Science and social studies teaching methods courses for these prospective teachers could emphasize the integration of ethical and scientific content related to the biotechnology spoken of previously in the elementary student section. If prospective teachers do not understanding how humans use science and technology to design the crops they value, how will their students gain such understandings?

Another area related to both science and social studies that needs to be addressed at the university level is the trade-offs of using agricultural technologies. Specifically prospective teachers do not understand how agriculture alters the land and how society's eating habits affect the way resources are used. This is of particular import considering, for example, that rain forest habitat destruction is a common topic studied in elementary school. Based upon the findings of this study, it appears that most teachers would be unable to link the eating of bananas and chocolate (something that most elementary students do much of) to the alteration of natural landscapes within the rain forests (monocultural practices require the destruction of indigenous habitats). In other words, most universities do not provide programs and curricula to help prospective teachers understand the trade-offs resulting from the food choices that society makes. Without the prospective teachers understanding this concept, there is little hope that elementary students will understand.

If formalized education can be thought of as the learning of ideas, concepts and information commonly held by society, then educational programs and materials can be designed to strengthen, construct, or reconstruct learner-held conceptions so they correspond with those that are commonly held by societies of experts.

3. Developmental Ideas and Collaboration between Agricultural and Science Education

Societies of experts--such as university agricultural and science educators--may find this study of particular interest as it underscores the need for cooperation between

them. Specifically, there are ideas missing in the curricular frameworks of both disciplines (See Chapter 2) that require each to teach agri-food system topics so that students develop schemata that are compatible with experts and allow them to question the hegemony within the system. For example, there are developmental ideas essential to understanding the agri-food system. By this I mean ideas that are foundational to developing a sequenced understanding of complex ideas. For example, there appear to be core biological concepts (plant and animal growth needs, competition among organisms, etc.) that undergird other more complex concepts. Without this initial structure, learners do not acquire the scaffolding for learning. A good example is pesticide use. To understand why humans use this technology one must understand that: 1) humans are animals that compete for food with other animals, e.g., insects, rodents, etc., 2) animals have growth requirements (food, water, shelter, air, space), 3) these growth requirements are in limited supply, 4) humans select certain plants and animals to grow for food, 4) animals and plants that humans grow can be food for competitors, 5) humans, to control animals and plants that destroy their food, employ technologies that kill them, limit their number, or prevent them from reaching the crop they choose to grow, and 6) humans must weigh trade-off of the use of technologies, such as pesticides, in regard to human health and safety and the environment.

Additional developmental ideas that surfaced in this study, but that can be fleshed out in other studies are:

- agricultural production systems--requiring an understanding of physical and biological resources as well as climates

- decline in biodiversity from farming--requiring an understanding of requirements for growth, food chains, energy transfer, soil erosion.

4. Teacher Preparation

In addition to curriculum development and developmental ideas, this study has implications for teacher preparation at the university level. The findings showed that prospective elementary teachers had difficulty understanding various aspects of the agri-food system benchmarks. To insure that elementary students are provided with the canonical knowledge in agriculture and science that undergirds agri-food system literacy, future teachers need background and knowledge that teach science concepts through pertinent agri-food system contexts. Further, this study showed that prospective teachers with real-world experiences in gardening, lawn maintenance, food preparation, etc. held rich and accurate agri-food system conceptions. Unfortunately, most elementary teachers are not presently trained in the use of experiential teaching (Hikawa and Trexler, in press) and are uncomfortable using agricultural examples (Trexler and Suvedi, 1998) as a context for instruction. Therefore, strategies to help prospective teachers learn to teach through experience are warranted. Interdisciplinary teacher preparation classes inclusive of science, social studies and agriculture could provide the necessary contextual background and skills to teach in ways that this study indicated were most contributory to agri-food system conceptual development.

A Final Thought

This dissertation focused broadly on determining what certain people in society understand about the agri-food system so they can make informed choices about the use of its science and technology. To do this, people need to possess an understanding of scientific and technological principles to assess implications for the environment and culture. Acquiring such understanding is a cumulative process that begins when people are very young. This study points out that there are areas where elementary students and their prospective teachers are well informed and others where they hold incomplete or no conceptions about the system. By ferreting out what people do and do not understand, educational programs, materials and experiences can be designed to foster agri-food system literacy.

APPENDICES

APPENDIX A

Review Committee

Review Committee

Committee Members for this dissertation were:

Dr. Charles W. Anderson, Professor
Department of Teacher Education
College of Education

Dr. Frank Bobbitt, Professor Emeritus
Department of Agricultural and Extension Education
College of Agriculture and Natural Resources

Dr. Lawrence Busch, Professor
Department of Sociology
College of Social Science

Dr. Kirk Heinze Associate Professor and Acting Chairperson
Department of Agricultural and Natural Resources Education and Communications System
College of Agriculture and Natural Resources

APPENDIX B

Synthesis of Selected Benchmarks from AAAS Benchmarks for Science Literacy and the California Agriculture Literacy Framework

A. Key concepts, benchmarks, language and applied context for elementary students

Key concepts	Curricular goals	Language	Applied context
I. Food and Fiber System			
A. What is agriculture?	1) Identify food and fiber products that come from plants and animals.	food, fiber, wood	Examples of clothing, shoes, wool, cotton lumber, meats, vegetables, milk
	2) Describe the variety of farms and their products.	small, large, family, corporate, farms, structure	ranches, gardens, horticulture greenhouses
	3) Describe how agriculture provides peoples' basic needs.	grow, food, clothing and shelter.	See objective 1
	4) Identify agriculture in their region, and describe the basic needs it provides.	forestry, livestock, dairy, fiber crop, grain	Local farms, nurseries, florists, lumber mills, food
	5) Describe the journey of a food or fiber product travels through from the farm to the consumer.	research, production, transportation, processing, marketing, distribution, consumption	Grocery stores, processing plants, wholesale markets, butcher store, restaurants
	6) Describe how agriculture uses natural resources to provide peoples basic needs .	soil, air, water , energy	See objective 2
	7) Explain the role of natural resource management in the agri-food system.	conservation, resources, management	DNR officers, forests, greenbelts

Key concepts	Curricular goals	Language	Applied contexts
II. Science: Agricultural - Environmental Interdependence			
A) How are parts of the ecosystem managed by humans related and how do they interact?	1) Explain how humans are part of a food chain or web, and describe their feeding relationships within the web.	consumers, producers, predator, prey, decomposers , top of chain	Humans, cows, pigs, deer, meat; wheat, corn, rice , grass, vegetables; slaughter of animals
	2) Describe the interaction with and interdependence of humans and their environment.	See objective 1	
	3) Describe competitive relationships between humans and other living things.	competition, limit, resources, humans, insects, weeds, rodents	Mice and rats in houses; weeds in gardens; cockroaches in kitchens
	4) Describe how crops depend on an area's climate and soil for growth.	temperature, dependent, habitat, soil, precipitation	Summer fruits, pine trees, winter lettuce from south US
B) How do humans manage crops to promote growth and reduce spoilage?	1) Describe basic growth requirements for plants and animals.	light, air, water, food, space, warmth, fertile soil	wood lots, gardens, rotting wood, lumber with termites
	2) Describe how crops may be lost to pests.	pest, damage, loss	Insects damage in gardens and on houseplants, larvae in corn-on-the-cob,
	3) Explain how crops are protected from weeds and pests.	kill, poison, crop protection	Bait for mice, rats, and birds, Sprays for weeds and insects
	4) Describe the positive and negative	poisons, resistance,	Larger and less blemished house

	impacts of using poisons to protect crops.	harmful, beneficial , alternative practices	plants, illness among farmworkers, birds- DDT
	5) Describe how foods may spoil before use.	heat, consumer, spoil, germs, decay, decompose, sanitation	Rotten meat, curdled milk, slimy lettuce, refrigerator gets turned off
C) What is the role of science and technology in the food and fiber system?	1) Explain why humans select certain plant varieties and animal breeds over others to grow for food and fiber.	taste, selection, nutrients, yield, profit	Selective breeding in cattle for milk , shelf-life of winter tomatoes, protein content of wheat
	2) Explain why irrigation and fertilizers are used to grow crops.	nutrients, soil, water, dry, increased production, arid	Miracle Grow ads on T.V, watering of lawns during summer, growing vegetables in the Western US
	3) Describe advantages of and methods to slowing down food spoilage.	heating, salting, smoking, drying, cooling, storage, decomposers	Beef jerky, dried fruit, frozen fruit, powdered milk, pickled pigs feet
	4) Identify the places of origin of common foods eaten by Americans.	state, countries, world	bananas- South and Central America, peanut butter- so. US, oranges- FL, CA & Brazil
	5) Describe how places too cold or too dry to grow certain crops can obtain food from places with more suitable climates.	trains, cargo planes, trucks, transportation, trade, roads, ships, fuel, energy use, climate, cold , dry, food	Lettuce and tomatoes trucked to Michigan in winter, cranberry juice in Arizona, maple syrup in Texas

Key concepts	Curricular goals	Language	Applied context
III. Cultural-historical			
A. How has the agriculture changed society.	1) Describe how society transitioned from a hunter gatherer to agrarian structure.	hunter gatherer, nomads, agriculture, domestication	Plains native American culture; nomadic African tribes, Northern Europeans in the new world
	2) Explain the affects of modern technology on farms, farmers and rural and urban communities.	machines, fewer farms, agriculture, farmers, efficiency, pollution, loss of jobs and culture	Animal power (Amish) vs. tractor power, loss of small farms, less farmers, loss of rural population
IV. Business and Economics			
A. How is agriculture and economics related?	1) Explain how surplus products (crop) allow for the development of trade.	surplus, supply, demand, trade, money	Grocery store, roadside vegetable stand, oversupply of tomatoes traded with neighbors
	2) Describe how each step in the food and fiber pathway adds value to a product.	pathway, value (costs), transportation, labor costs, energy costs	Cost of a fast food hamburger vs. one made at home, cost of a potato vs. frozen French fries
V. Food, Nutrition, and Health			
A. Why do we choose the foods we do?	1) Describe the factors that influence our food choices.	survival, economic, cultural, convenience, information, advertising	Snack foods, fast food, ethnic foods
B. How safe is the	1) Explain how food	storage,	Washing of food

food we eat?	should be handled to ensure health and proper nutrition?	preparation, sanitation, expiration dates	before eating, cleaning food preparation areas, refrigeration of foods

B. Key concepts, benchmarks, language and applied context for prospective elementary teachers

Key concepts	Curricular Goal	Language	Applied context
II. Science: Agriculture - Environmental Interdependence			
A. What is the role of science and technology in the food and fiber system?	1) Describe how new varieties of farm plants and animals have been engineered to produce new characteristics.	genetic engineering, cloning, natural selection, mutation	Drought resistant plants, cloning of sheep, BST hormone in milk production
III. Historical and Cultural			
A. How has the modern agri-food system impacted society?	1) Explain how agricultural technology changed the way people live and work in the US over the last century.	farms, cities, population, society, shift, employment, increased production, time	Migration of rural people to cities, farmworker unionization, migrant labor
	2) Describe trade-offs inherent in the use of agricultural technology in terms of environment and human culture.	increased production, sustainability, land degradation, efficiency, higher disposable income, pesticides, fertilizers, employment, pollution , loss of	Inexpensive food, algae blooms in waterways from fertilizer run-off, nationwide E coli scares, increased petroleum consumption for transport of

		culture, preservation, exploitation, erosion, conservation	crops
IV. Business and Economics			
A. What are the roles of local, state and national governments in the agri-food system?	1) Explain why the US government monitors and intervenes in the agri-food system?	inexpensive food supply, high-quality, stable , residues, food poisoning	Monitoring of the USDA, FDA, BLM; Alar scare in apple production
	2) Describe reasons for governmental regulations to protect farmer from abrupt changes in environmental conditions and from competition by farmers in other countries.	competition, natural disaster, supply, demand, food security	Drought or floods, insect or disease plague, over-production of crops, subsidies for farmers
V. Food Nutrition and Health			
A. How is nutrition related to agriculture.	1) Explain how a person's food choices affects the use of the environment and culture.	processed foods, transportation, energy use, environmental costs, employment, nutrition,	Kiwi fruit from New Zealand in the winter in Michigan, a diet high in meat products, loss of diversity on the planet due to monoculture

APPENDIX C

Expert Concept Maps for the Study of Key Concepts and Benchmarks

Figure 1. Concept Map for the Expert Key Concept: I.A. What is agriculture? Bencmarks 1-4.

I.A.1 Identify food and fiber products that come from plants and animals.

I.A.2. Describe the variety of farms and their products.

I.A.3 Describe the journey of a food or fiber product as it travels from farm to consumer.

I.A.4 Describe how agriculture uses natural resources to provide peoples' basic needs .

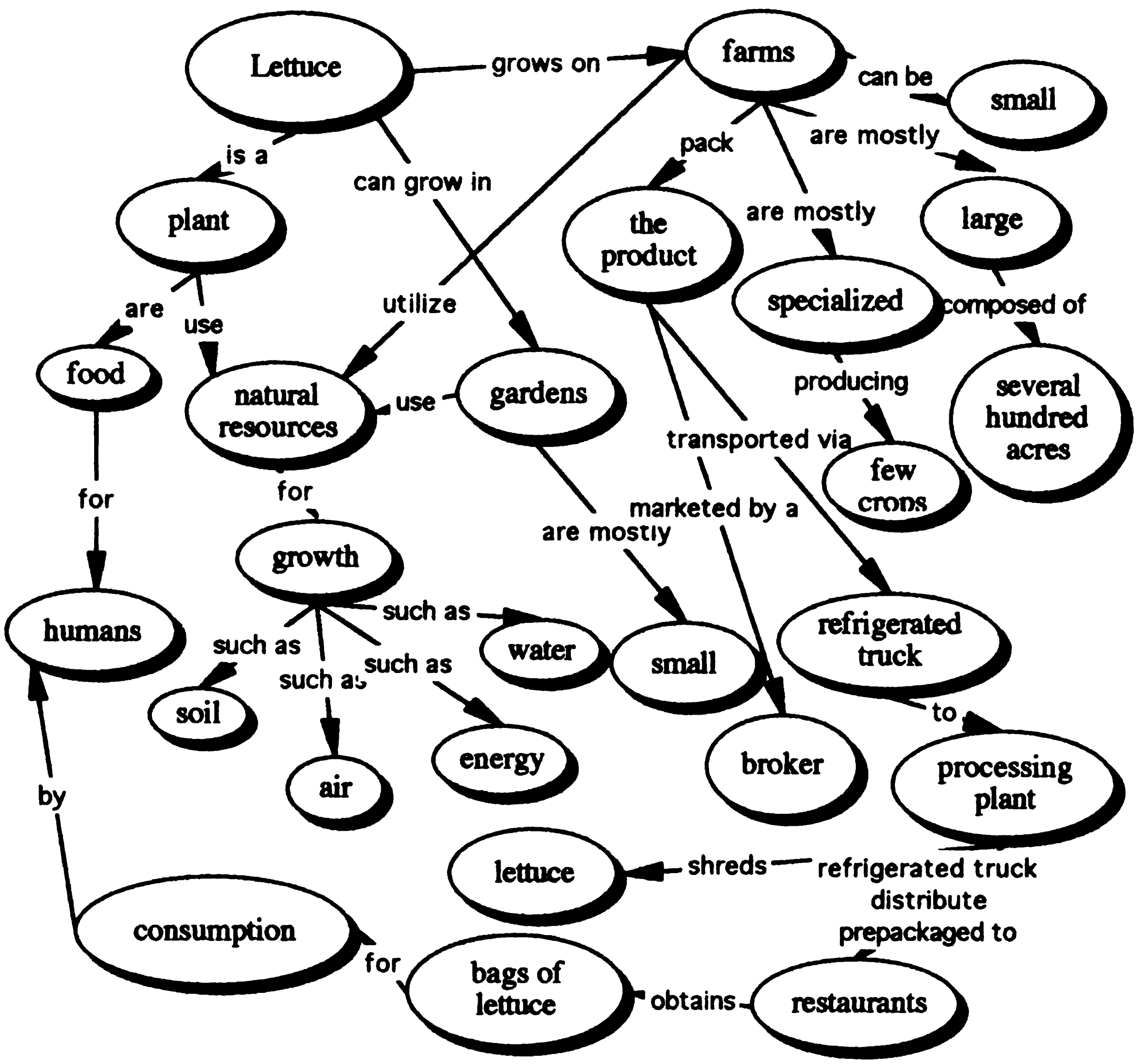


Figure 2. Concept Map for the Expert Key Concept: II.A. How are parts of the ecosystem managed by humans related and how do they interact? Benchmark 1.

II.A.1 Describe how crops depend on an area's climate and soil for growth.

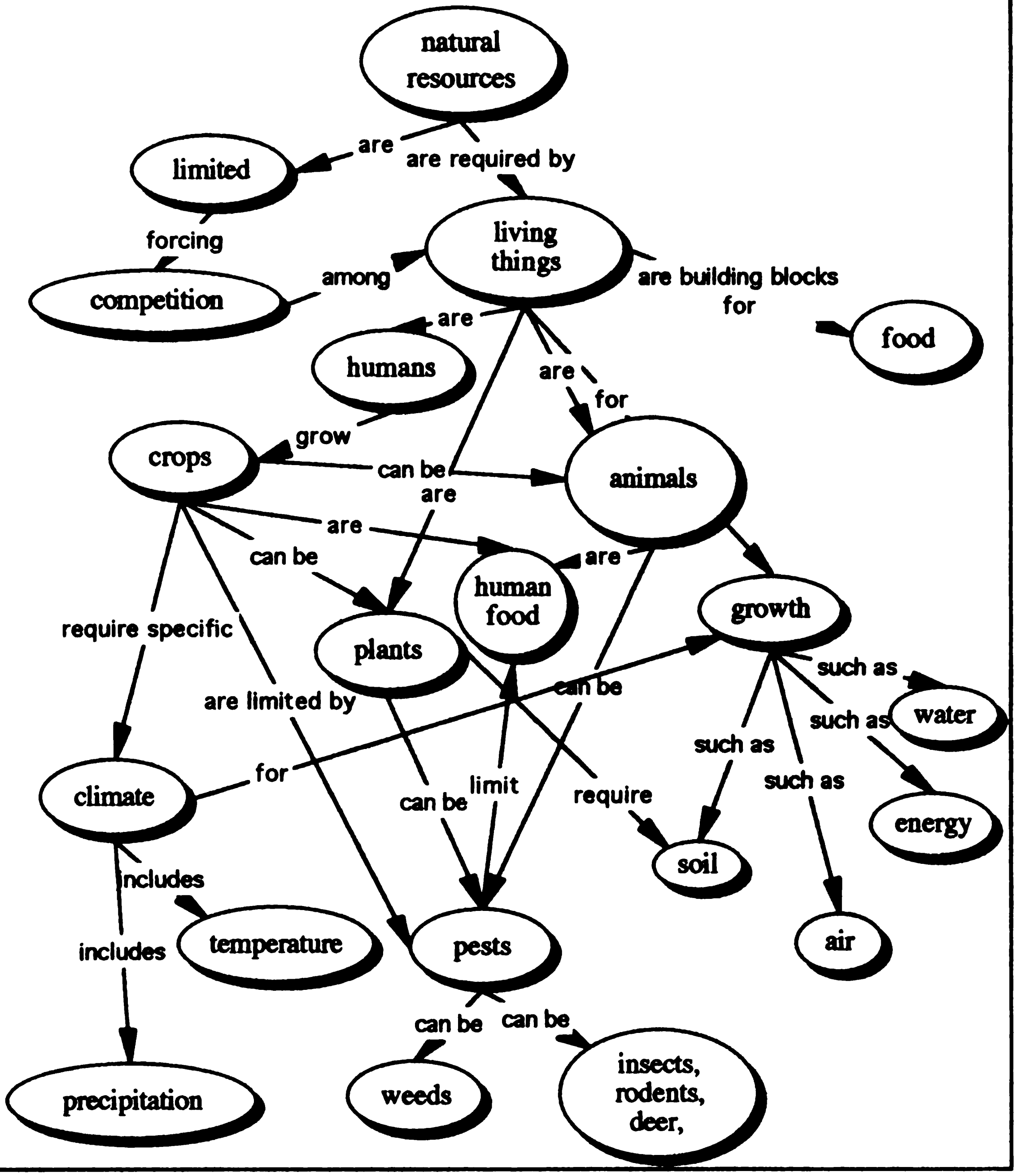


Figure 3. Concept Map for the Expert Key Concept: II.B. How do humans manage crops to promote growth? Benchmark 1.

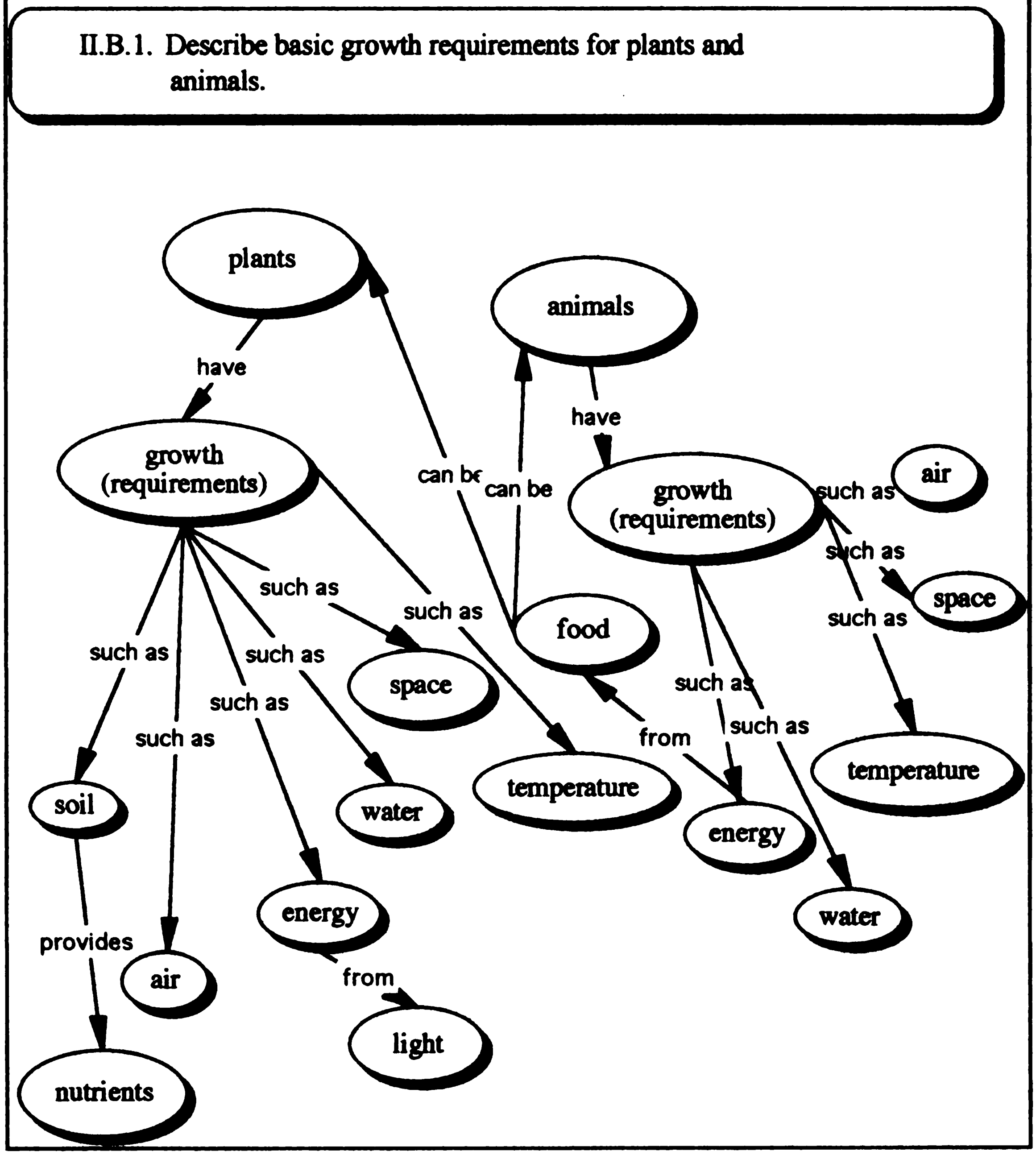


Figure 4. Concept Map for the Elementary Student Key Concept: II.B. How do humans manage crops to promote growth? Bencmark 2 & 3.

II.B.2. Describe how crops may be lost to pests.

II.B.3. Explain how crops are protected from pests.

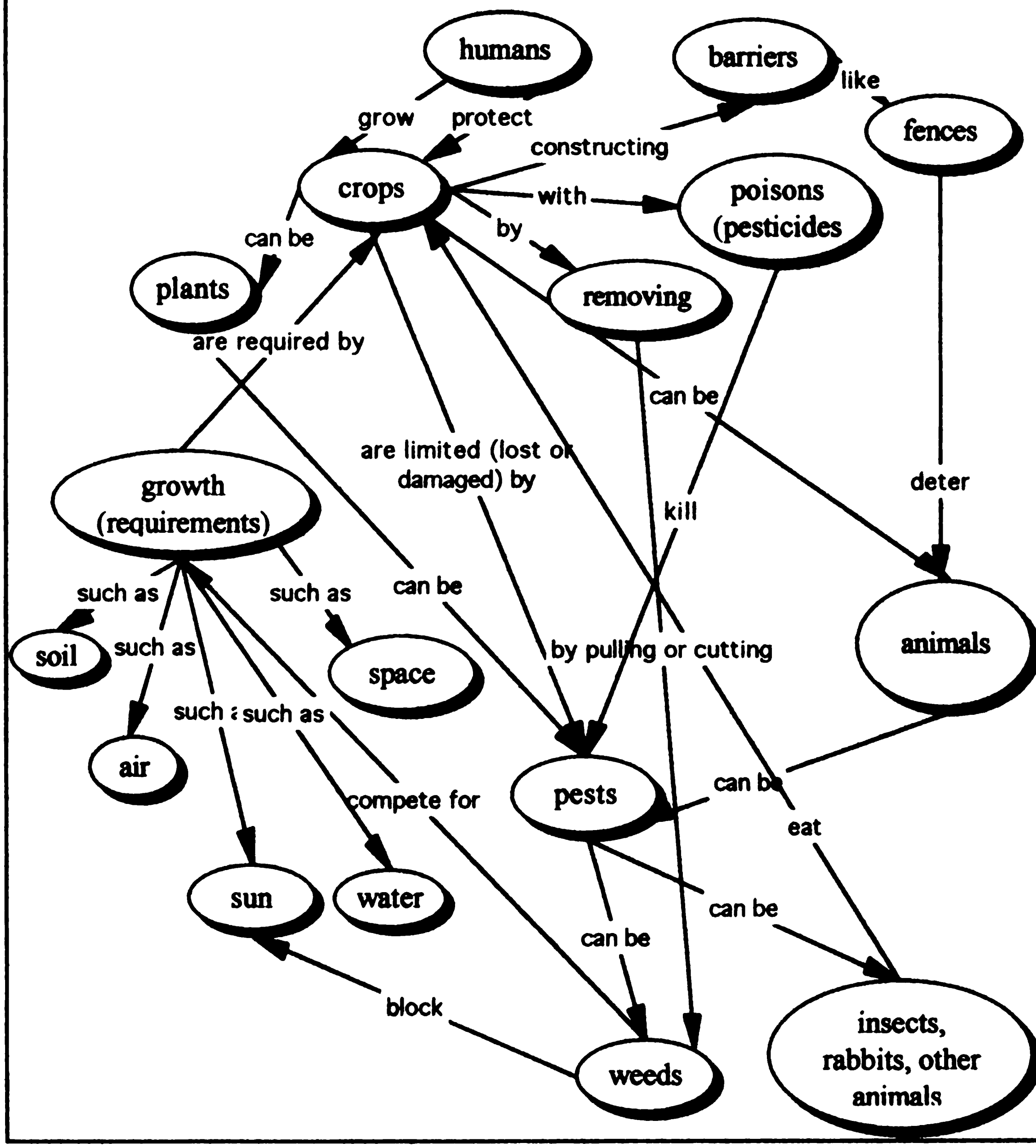


Figure 5. Concept Map for the Expert Key Concept: II.B. How do humans manage crops to promote growth? Benchmark 4.

II.B.4. Describe the positive and negative impacts of using poisons to protect crops.

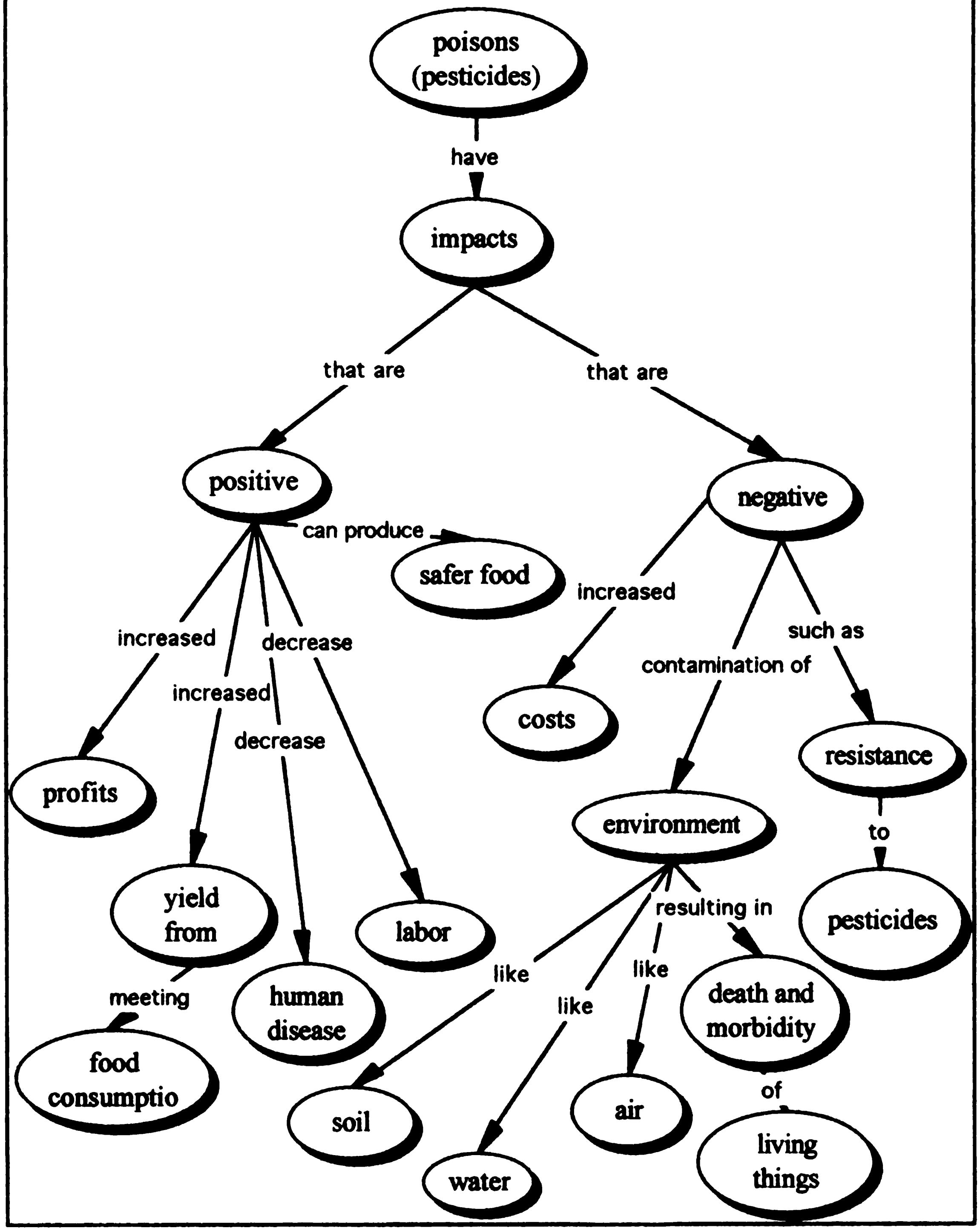


Figure 6. Concept Map for the Expert Key Concept: II.C. What is the role of science and technology in the food and fiber system? Benchmark 1.

II.C.1. Explain why irrigation and fertilizers are used to grow crops.

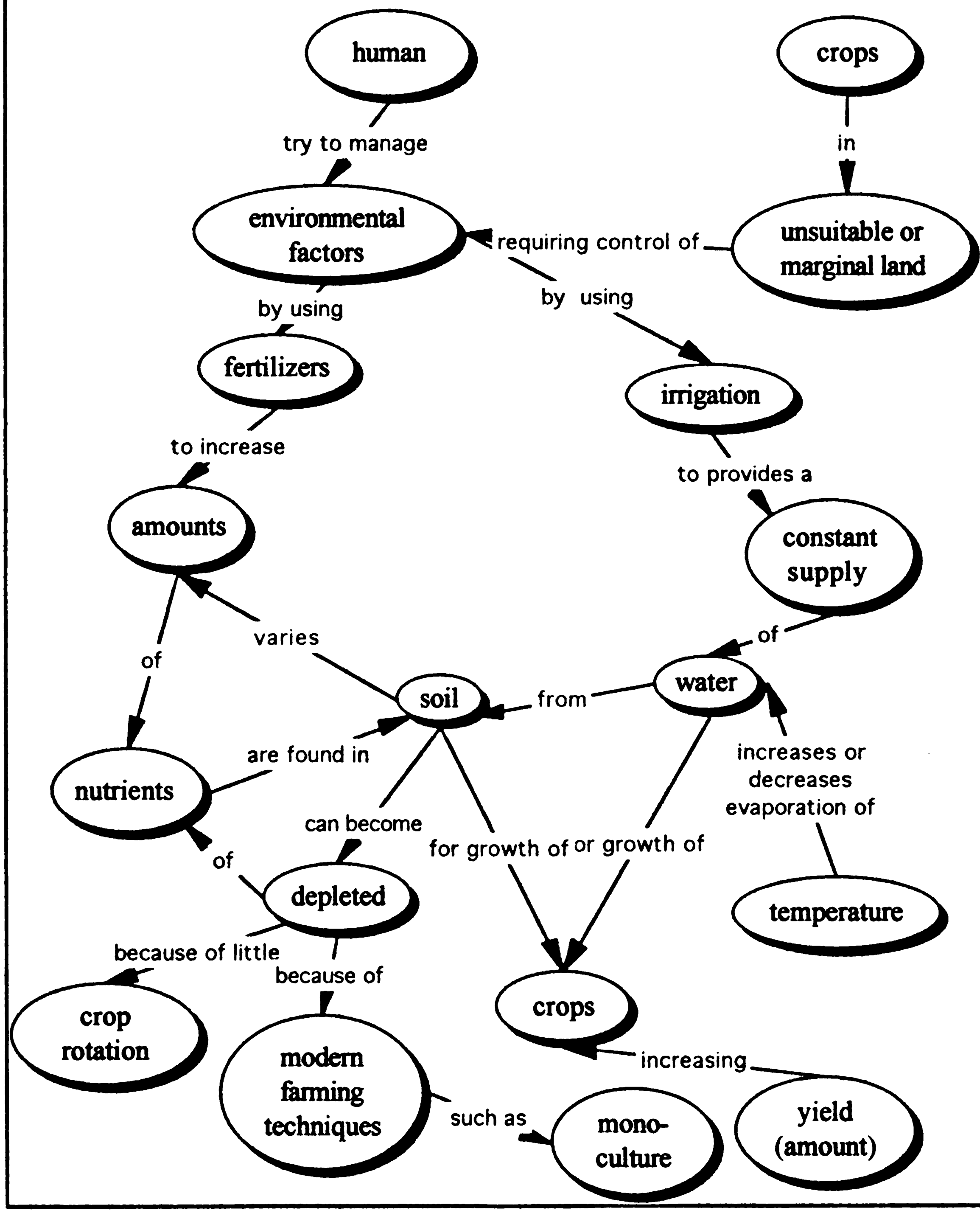


Figure 7. Concept Map for the Expert Key Concept: II.C. What is the role of science and technology in the food and fiber system? Benchmarks 2 & 3.

II.C.2. Identify the places of origin of commons foods eaten by Americans.

II.C.3. Describe how places too cold or too dry to grown certain crops can obtain food from places with more suitable climates.

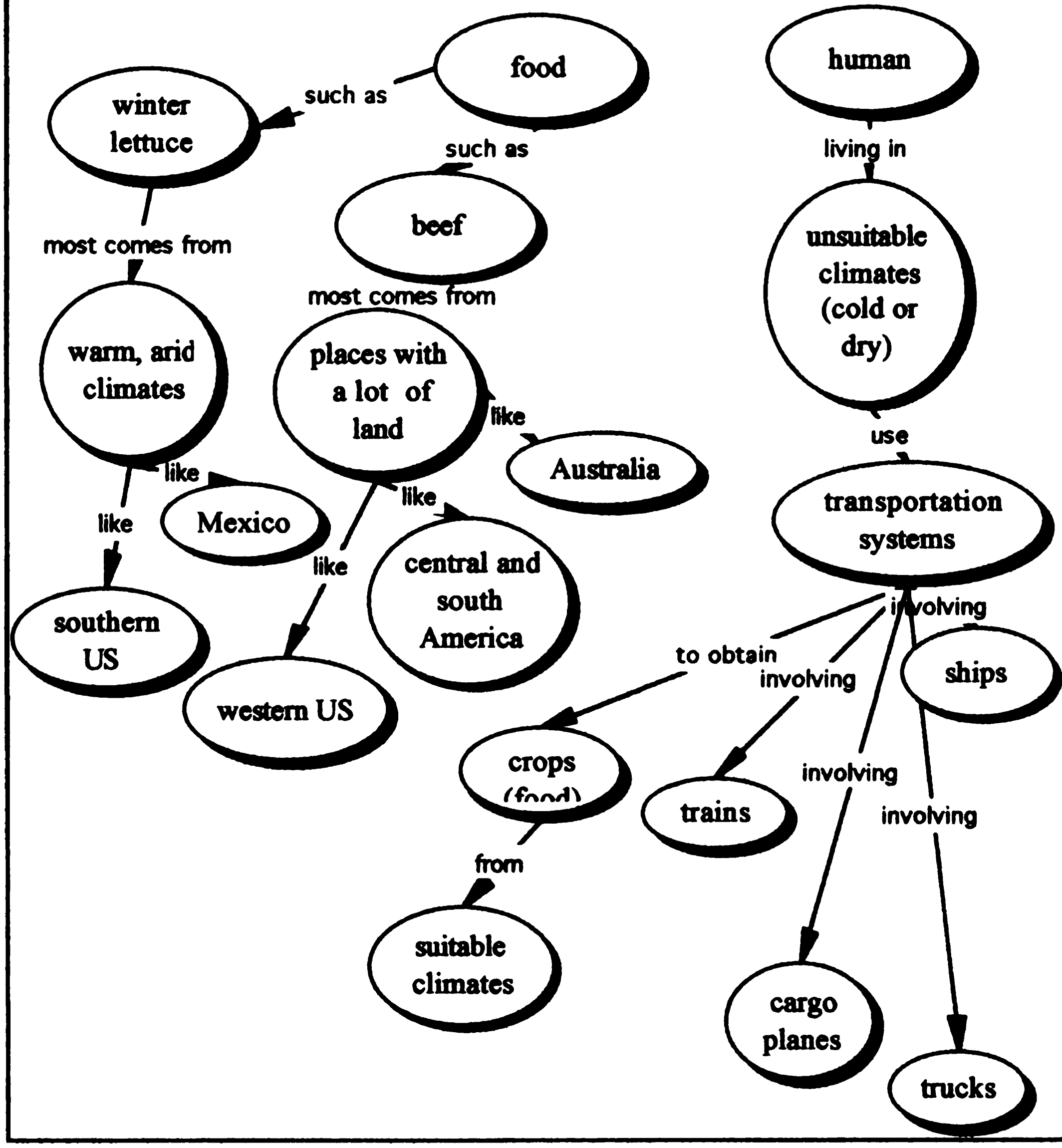


Figure 8. Concept Map for the Elementary Student Key Concept: III. How has agriculture changed society? Benchmark 1.

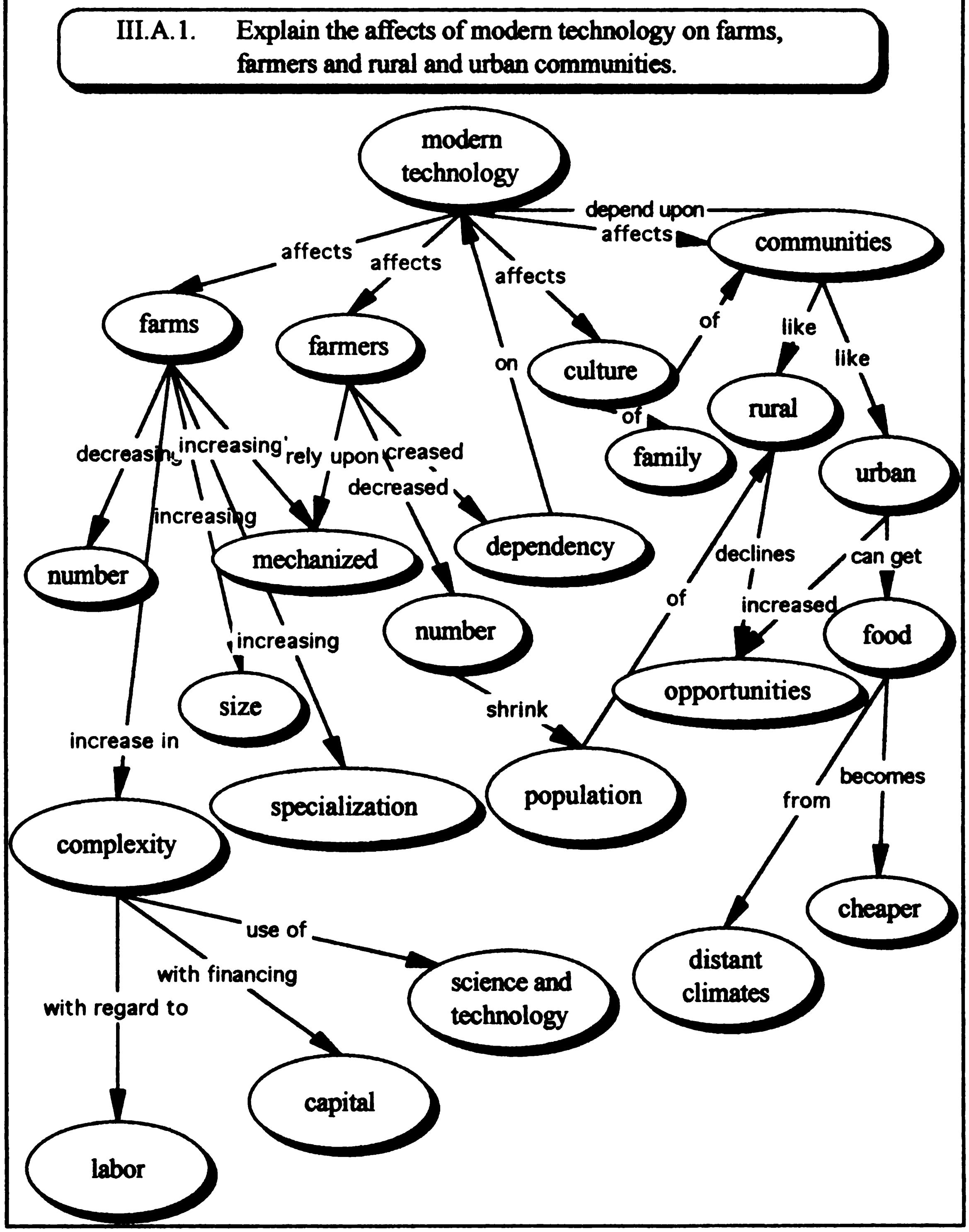


Figure 9. Concept Map for the Elementary Teacher Key Concept: II. A. What is the role of sceince and technology in the food and fiber system?

II.A.1. Describe how new varieties of farm plants and animals have been engineered to produce new characteristics.

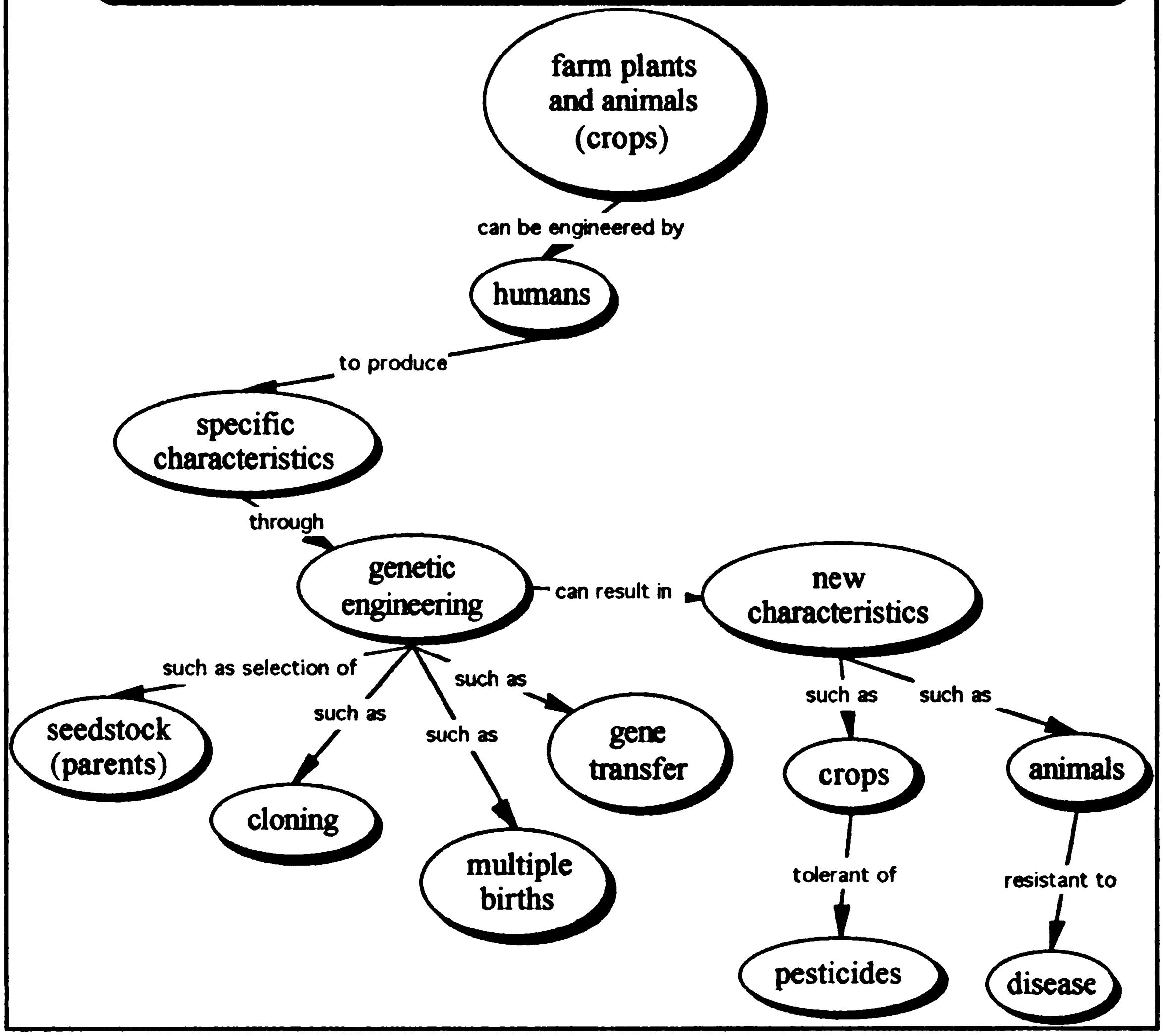


Figure 10. Concept Map for the Elementary Teacher Key Concept: A. How has the modern agri-food system impacted society? Benchmark 2.

III.A.2. Describe trade-offs inherent in the use of agricultural technology in terms of environment and human culture.

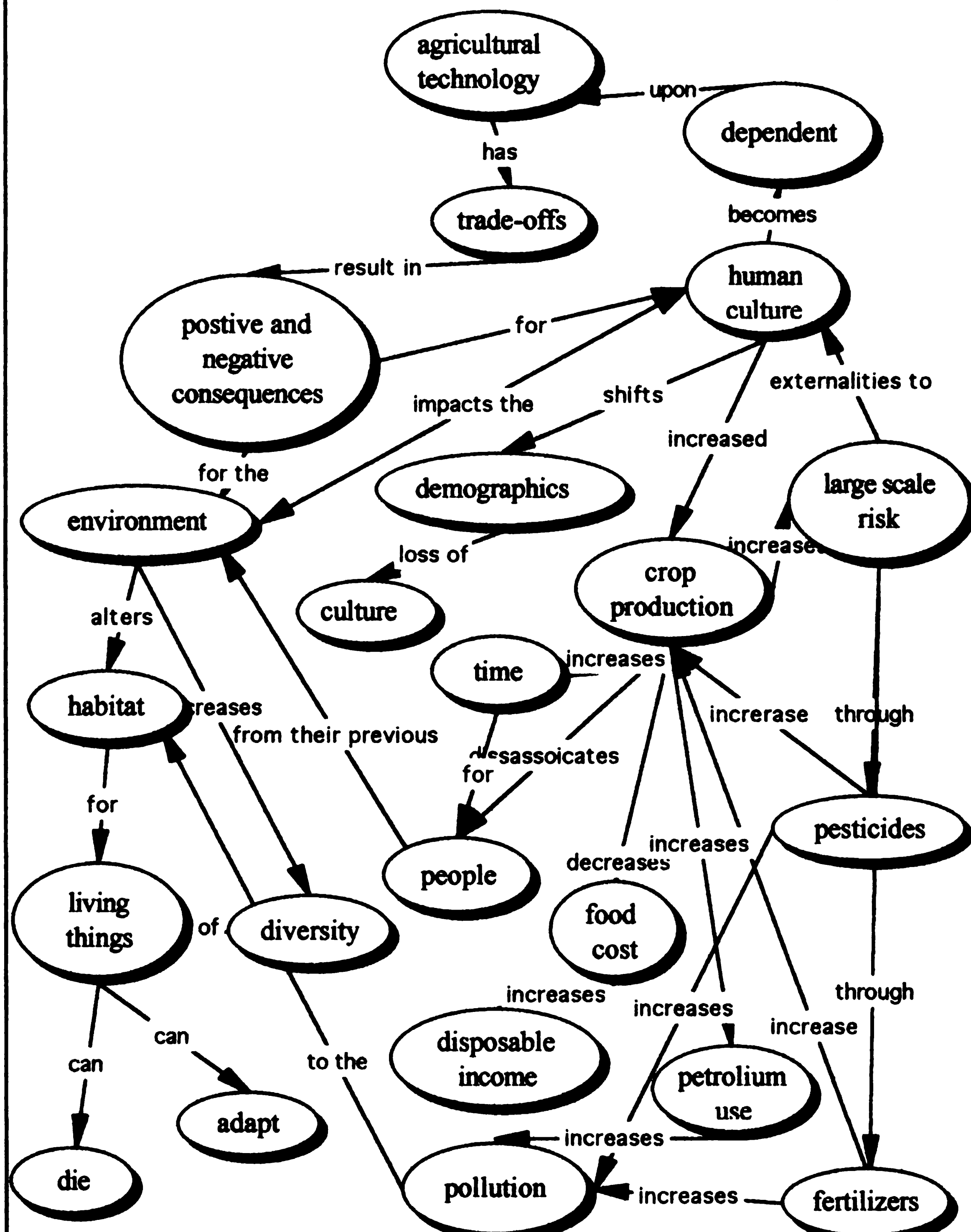
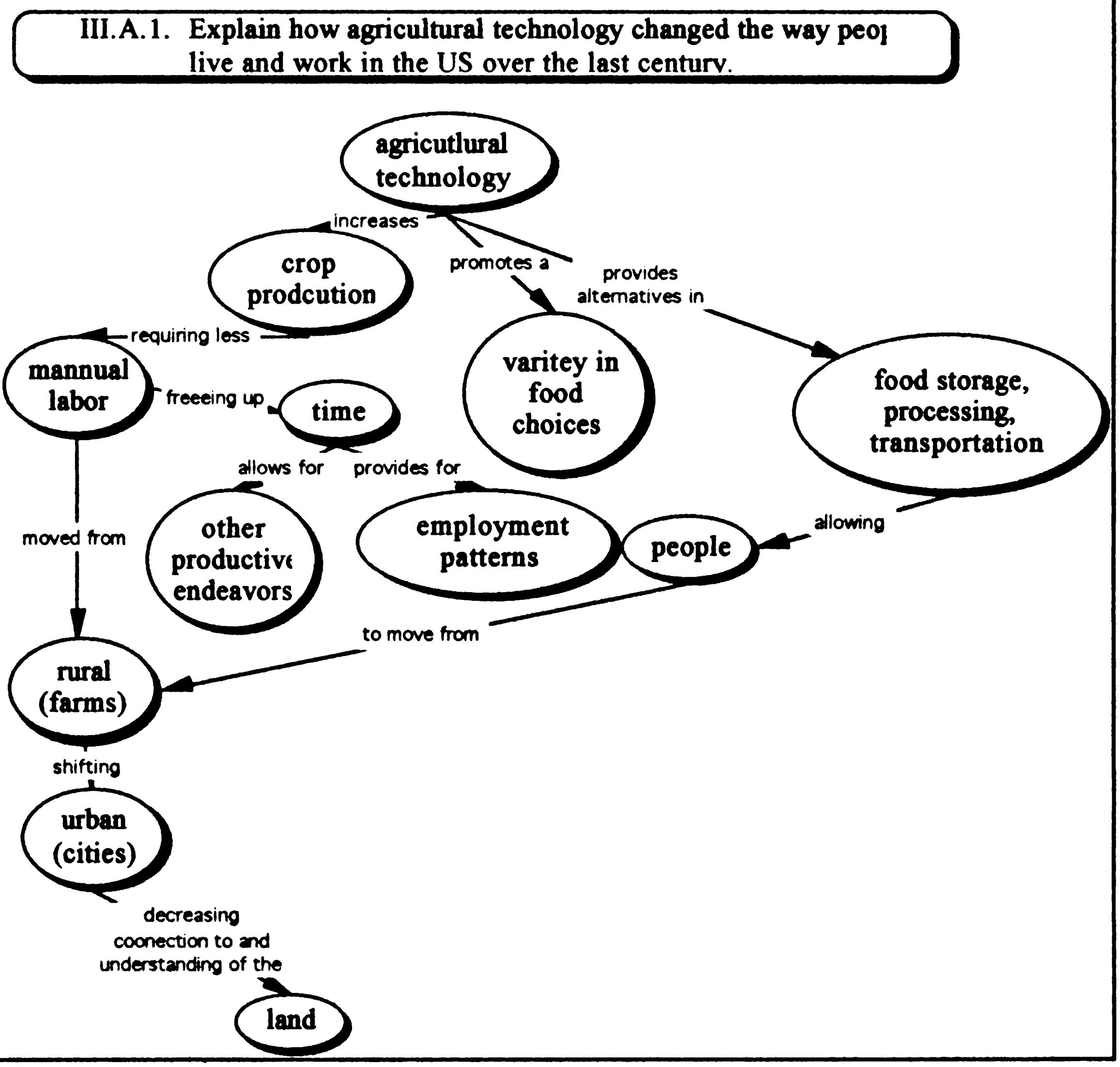


Figure 11. Concept Map for the Elementary School Teachers Key Concept: II A. How has the modern agri-food system impacted society? Benchmark 1.



APPENDIX D

Students' Understanding of the Expert Key Concept II.B.2 & 3

Figure 12. Jay's Understanding of Key Concept: II. B. How do humans manage crops to promote growth?

II.B.2. Describe how crops may be lost to pests.

II.B.3. Explain how crops are protected from pests.

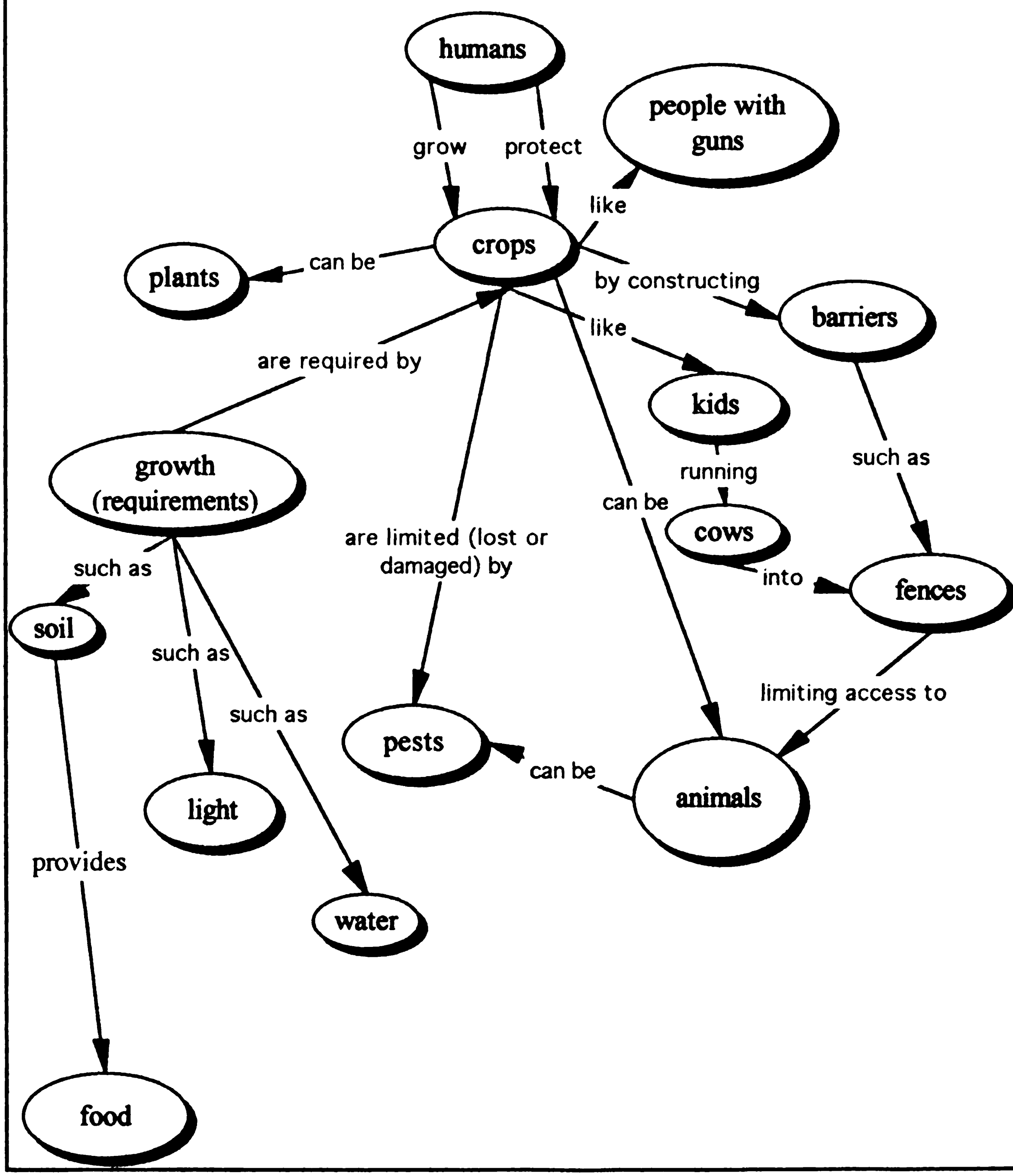


Figure 13. Jill's Understanding of Key Concept: II.B. How do humans manage crops to promote growth?

II.B.2. Describe how crops may be lost to pest

II.B.3. Explain how crops are protected from pests.

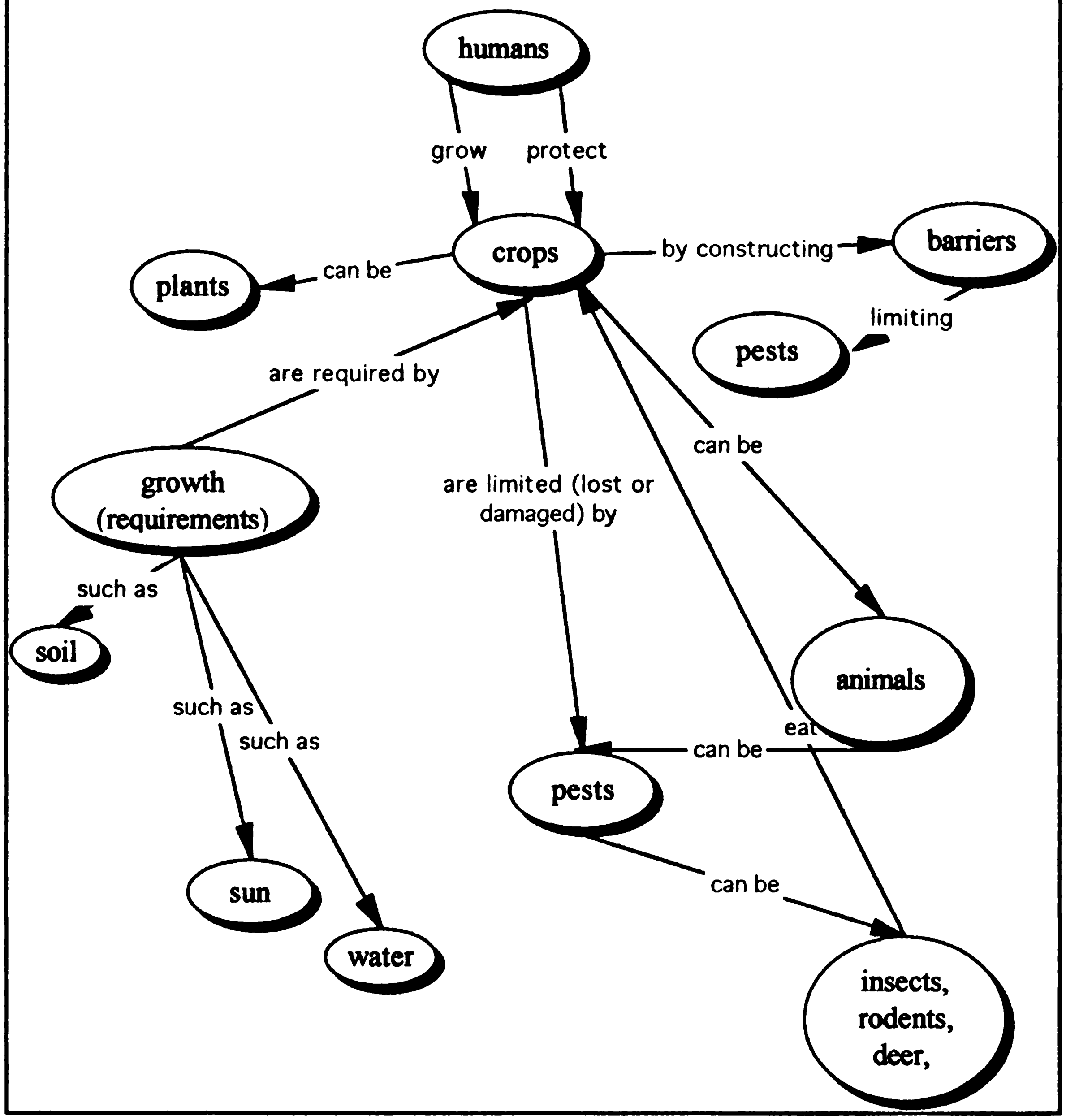


Figure 14. Thom's Understanding of: Key Concept: II.B. How do humans manage crops to promote growth?

II.B.2. Describe how crops may be lost to pests.

II.B.3. Explain how crops are protected from pests.

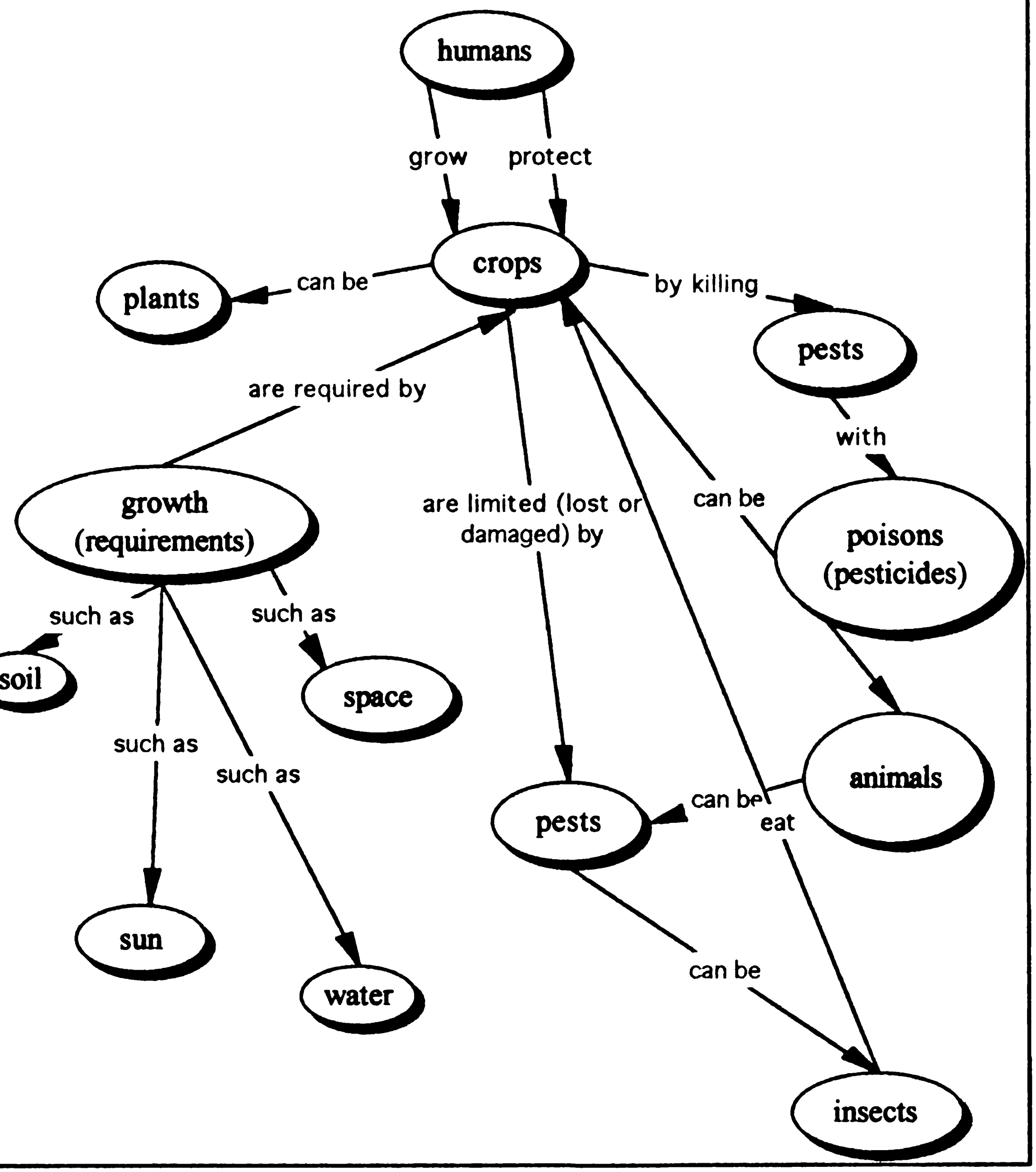


Figure 15. Jim's Understanding of Key Concept: II.B. How do humans manage crops to promote growth?

II.B.2. Describe how crops may be lost to pests.

II.B.3. Explain how crops are protected from pests.

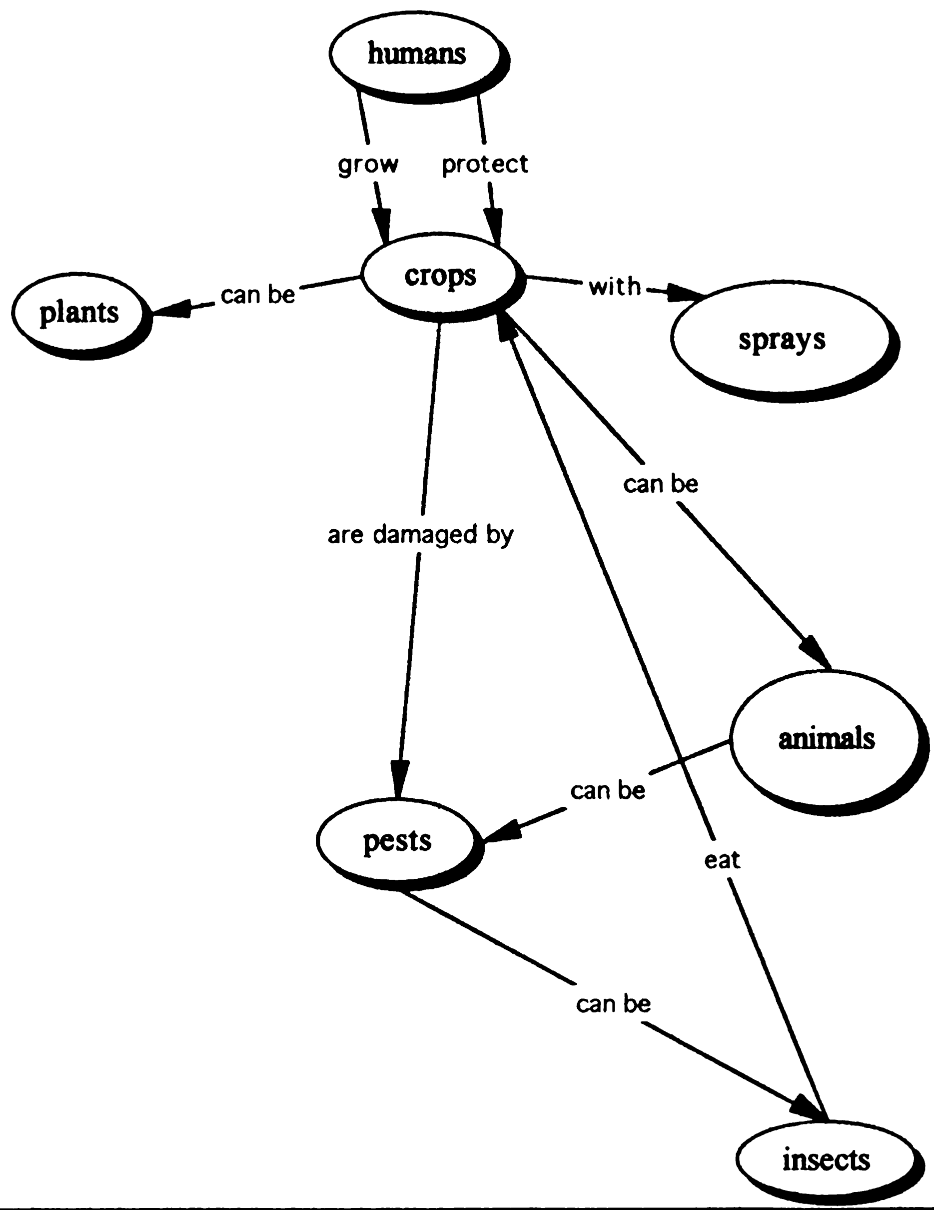


Figure 16. Mona's Understanding of Key Concept: II.B. B. How do humans manage crops to promote growth?

II.B.2. Describe how crops may be lost to pests.

II.B.3. Explain how crops are protected from pests.

Did not discuss anything about pests. Never heard of pesticides.

Figure 17. Sara's Understanding of Key Concept: II.B. B. How do humans manage crops to promote growth?

II.B.2. Describe how crops may be lost to pests.

II.B.3. Explain how crops are protected from pests.

Did not discuss anything about pests. Never heard of pesticides.

Figure 18. Tim's Understanding of Key Concept: II. B. How do humans manage crops to promote growth?

II.B.2. Describe how crops may be lost to pests.

II.B.3. Explain how crops are protected from pests.

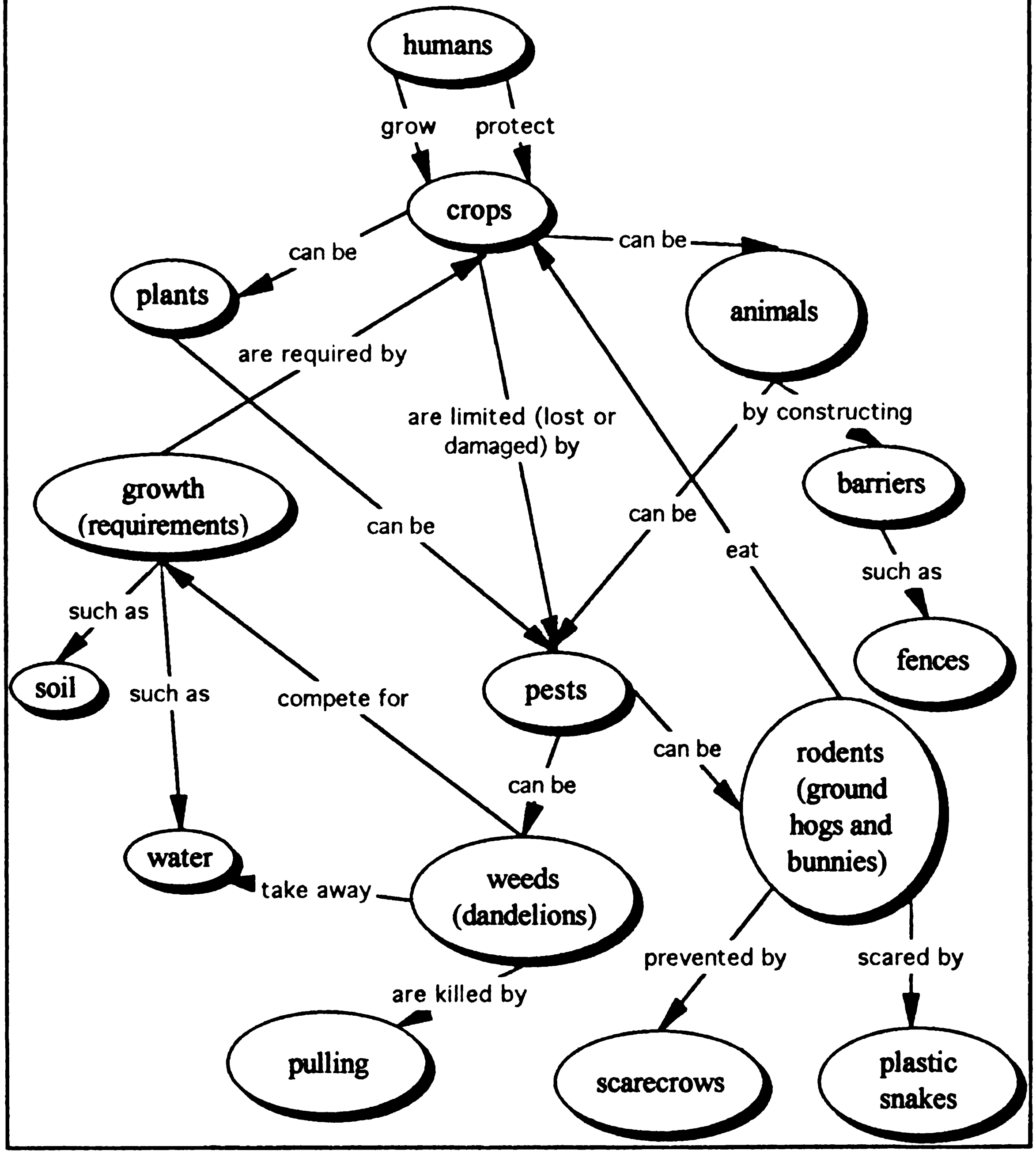


Figure 19. Ema's Understanding of Key Concept: II.B. How do humans manage crops to promote growth?

II.B.2. Describe how crops may be lost to pests.

II.B.3. Explain how crops are protected from pests.

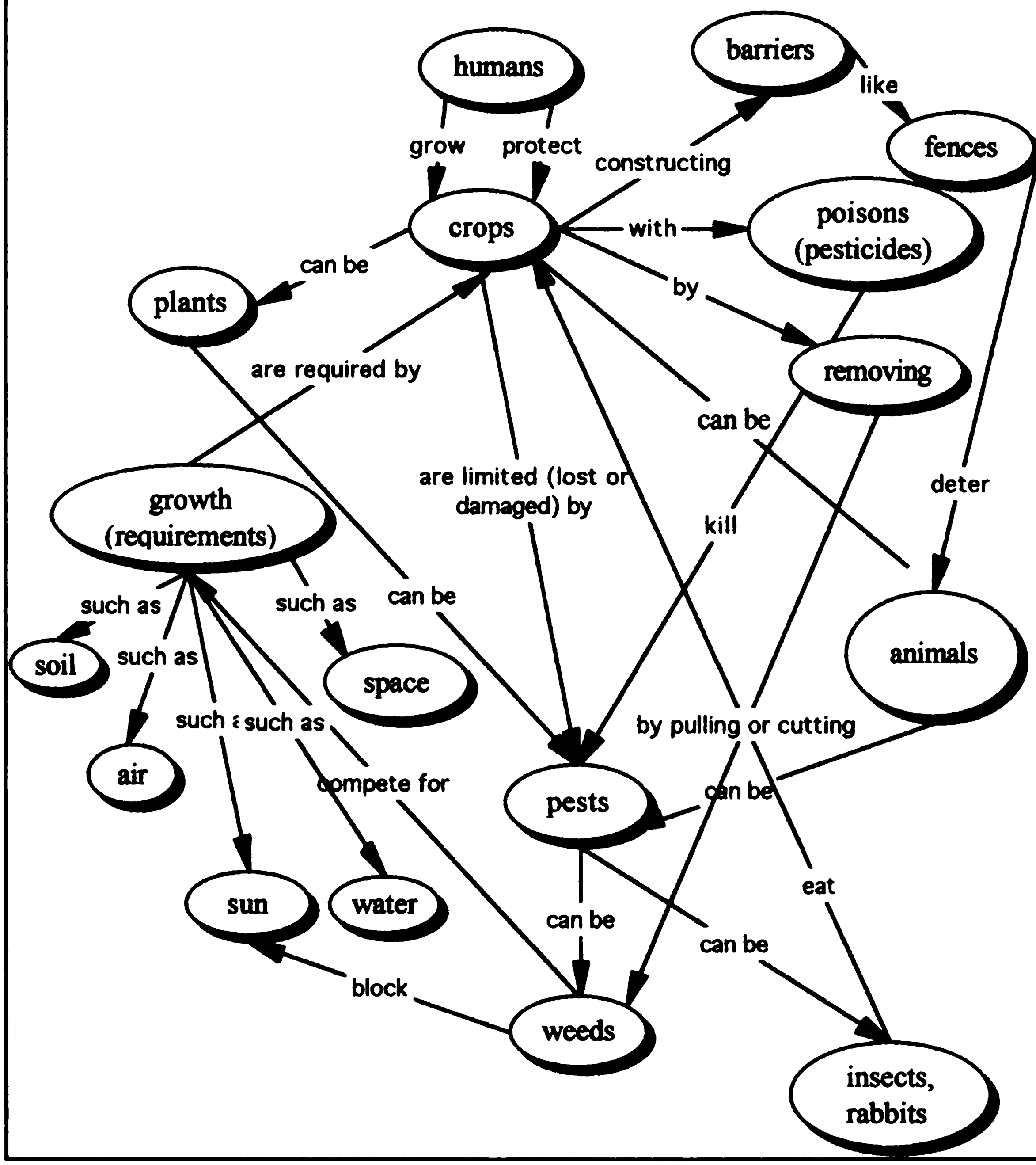
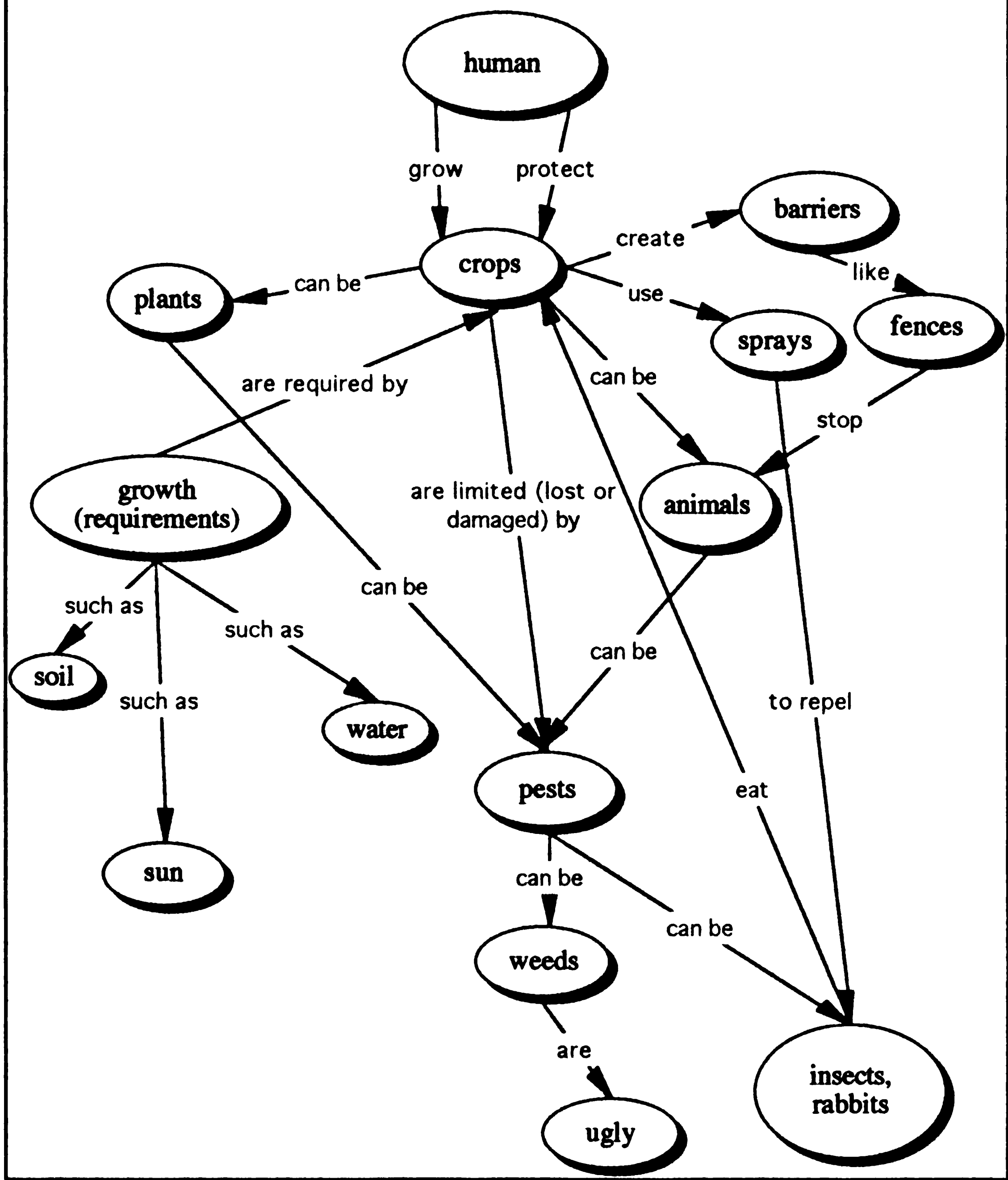


Figure 20. Liz' Understanding of Key Concept: II.B. How do humans manage crops to promote growth?

II.B.2. Describe how crops may be lost to pests.

II.B.3. Explain how crops are protected from pests.



APPENDIX E

Interview Prompts

Elementary Interview Prompts

Hi. Today I'm going to ask you some questions about where food comes from. You will probably have a pretty good idea about some of the things I am going to ask, others you might not. I am interested in finding out what you do and don't know. Sometimes I might ask you questions to push you as far as you can go about a certain topic. Do you have any questions?

Ok, let's get started. Can you separate the BigMac™ in front of you in any way that makes sense to you?

Why did you separate it in the way you did?

Research Objective 1) What are informants' backgrounds and experiences?

What grade are you in?

Who do you live with?

What do they do for work?

Where did you grow up? Can you describe the area?

Do/did you ever go with your parents to buy food? Where do you go?

Do you prepare your own food at home? What do you like to cook?

Have you ever been involved in growing food to eat?

Research Objective 2) How do student understandings of the agri-food system compare to goal conceptions based upon a synthesis of Project 2061's <u>Benchmarks for Science Literacy</u> and the <u>California Agricultural Literacy Framework</u>?

Research Objective 3) How do prospective elementary teacher understandings of the agri-food system compare to goal conceptions based upon a synthesis of Project 2061's <u>Benchmarks for Science Literacy</u> and the <u>California Agricultural Literacy Framework</u>?

Key Concept: I.A. What is the agri-food system?

Benchmarks

1. Identify food and fiber crops that come from plants and animals.

2. Describe the variety of farms and their products.
3. Describe the journey of a food or fiber product as it travels from the farm to the consumer.

Key Concept II.A. How are parts of the ecosystem managed by humans related, and how do they interact?

Benchmark

2. Describe how crops depend on an area's soil for growth.

Key Concept II.C. What is the role of science and technology in the food and fiber system?

Benchmark

2. Identify places of origin of common foods eaten by Americans.
3. Describe how places too cold or too dry to grow certain crops can obtain food from places with more suitable climates.

Can you tell me a little about where the stuff that is on the cheeseburger came from? Let's just focus on the lettuce. Where did it come from? Can you trace back how it got to McDonalds™?

Can you talk about the what you think the place looked like where the lettuce was grown? What did the lettuce look like when it was growing? Were there other things growing near them?

Can you tell me about the size of the place where the lettuce came from? Land is measured in acres, which are about the size of a football field. How many football fields do you think made up the place where the lettuce was grown?

Key Concept: I.A. What is the agri-food system?

Benchmark

4. Describe how agriculture uses natural resources to provide peoples basic needs.

Key Concept: II.A. How are parts of the ecosystem managed by humans related and how do they interact?

Benchmark

2. Describe how crops depend on an area's climate and soil?

Key Concept: II.B.

Benchmarks

1. Describe the basic growth requirements of plants and animals.
2. Describe how crops may be lost to pests.
3. Explain how crops are protected from weeds and other pests.
4. Describe the positive and negative impacts of using poisons to protect crops.

Key Concept: II.C. What is the role of science and technology in the food and fiber system?

Benchmark

1. Explain why irrigation and fertilizers are used to grow crops.

Key Concept: II.A

Benchmark

1. Describe competitive relationships between humans and other living things?

Can you tell me what plants need in order for them to live?
Can you talk about what the farmer might need to make sure the lettuce gets so that it grows? How would they do this?
Is there anything that the farmer must protect the plants from? Why would he need to do that?

Depending on the level of understanding, pesticides and their effects and trade-offs were probed. Similarly, if irrigation, fertilizers or use of chemicals surfaced, questions probed these topics.

What do the pesticides (chemicals) do? How do they do it? Can you think of any positive or negative things about using these things (pesticides/chemicals)? If they are negative, why do farmers use them?

Meat

The same Key Concepts and Benchmarks were addressed relative to the meat, except II.A.2., II.B.1., II.B.4, II.C.1. Essentially the same questions were asked for this commodity.

Key Concept: III.A. How has agriculture changed society.

Benchmark:

1. Explain the effects of modern technology on farms, farmers, and rural and urban communities.

Do you think there are more or fewer farmers in the US today as compared to 70 years ago? Why do you think so? So what has allowed this to happen? How does this affect people?

Additional Questions for Prospective Elementary Teachers

Key Concept: II.A. What is the role of science and technology in the agri-food system?

Benchmark

1. Describe how new varieties of farm plants and animals have been engineered to produce new characteristics.

If a farmer wanted to improve the amount or quality of animals used for beef, how do you think he would go about it? Have you heard of any emerging science or technologies that might help farmers get better animals?

Key Concept: III. B. How has the modern agri-food system impacted society?

Benchmark

1. Explain how agricultural technology changed the way people live and work in the US over the last century.
2. Describe trade-offs inherent in the use of agricultural technology in terms of the environment and human culture.

Can you tell me how you think the ___________ (a technology stated by the informant) has changed the way people live and work over the last century?

Can you think of any trade-offs (positive or negative consequences) that could result from the use of these agricultural technologies?

APPENDIX F

Parental Consent Letter

Parent Consent Letter

Date

Dear parent/guardian:

I am a doctoral student in the Department of Agricultural and Extension Education at Michigan State University. I am conducting a research project on student perceptions and understandings of the human food system. This is a personal interest of mine, since I have taught students in urban settings about the importance of food and food production's effects on the environment.

My research will involve two groups of people. The first is elementary school students; the second is the college juniors and seniors who plan on teaching elementary students. I first plan to determine elementary student understandings, and then compare these to what prospective teachers understand. There is little research on this topic. Through this research, I hope to inform people about the absence of this subject in our public schools.

To conduct this research, I will interview people from the two groups described above. These interviews will not take more than 45 minutes and will be video taped so that I can refer back to them at a later date. I will pay $6.00 for the interview.

All responses will be kept in strict confidence. Participants' request to stop the interview or to stop the video recording will be honored immediately upon request. Since my work involves minor children, I need to obtain permission from their guardian for the interview. If you will allow your child to participate, please fill out the attached form.

Thank you for considering to allow me to interview your child for this study. If you have any further questions, please contact me.

Sincerely,

Cary Trexler
Doctoral Candidate
trexlerc@pilot.msu.edu
(517) 355-6580 W

APPENDIX G

Elementary Student Release Form

Elementary Student Release Form

I, ______________________________, agree to participate in the research study described in the attached letter. The study has been explained to me and I have been informed of the potential benefits and possible risks of participation.

I further understand that a pseudonym will replace my real name in any report of the research findings and that any identifying information about myself will be deleted or protected with pseudonyms. My identity may be known to the principal investigators but will be kept confidential. I may refuse to answer any questions or to stop the interview at any time. I may ask for the video tape recorder to be turned off at any time during the interview.

$6.00 per hour of interview time will be paid to the guardian.

I, ______________________________, would prefer not to participate.

______________________________________Participant's Name
please print

______________________________________Signature

____________________Date ________________________Phone

My child has permission to participate in the research study described in the attached letter.

______________________________________Guardian Name
please print

______________________________________Signature

____________________Date ________________________Phone

APPENDIX H

Prospective Teacher Release Form

Prospective Teacher Release Form

I, ________________________________, agree to participate in the research study described in the attached letter. The study has been explained to me and I have been informed of the potential benefits and possible risks of participation.

I further understand that a pseudonym will replace my real name in any report of the research findings and that any identifying information about myself will be deleted or protected with pseudonyms. My identity may be known to the principal investigators but will be kept confidential. I may refuse to answer any questions or to stop the interview at any time. I may ask for the video tape recorder to be turned off at any time during the interview.

I understand that my decision to participate or not to participate will not affect my grade received in the course which my participation was solicited. I will be paid $6.00 per hour of interview time.

I, ________________________________, would prefer not to participate.

______________________Date   _________________________Phone

____Name
please print

____Signature

BIBLIOGRAPHY

BIBLIOGRAPHY

American Association for the Advancement of Science. (1989). Science for all Americans. Washington, DC: Author.

American Association for the Advancement of Science. (1993). Benchmarks for science literacy. NY: Oxford University Press.

Anderson, C. W. (1994). Teaching content in a multicultural milieu. Zeitschrift für Pädagogik, 33, 127-42

Anderson, C. W. (1995). Designing a clinical interview. Class handout from CEP 806: Psychological Foundations of Science Education: Michigan State University: East Lansing.

Anderson, C., & Roth, C. (1989). Teaching for meaningful and self-regulated learning of science. In Advances in research on teaching, Vol. 1 (pp. 265-309). JAI Press Inc.

Anderson, O. R., & Demetrius, O. J. (1993). A flow map method of representing cognitive structure based on respondents' narrative using science content. Journal of Research in Science Teaching, 28, 305-313.

Anderson, R.C., Spiro, R.J., & Anderson, M.C. (1978). Schemata as scaffolding for the representation for information in connected discourse. American Educational Research Journal, 15 (3), 433-440.

Arrow, K . (1987). Rationality of Self and Others in an Economic System. In R. Hogarth and M. Reder (Eds.), Rational choice. University of Chicago Press.

Bartlett, R. (1989). Economics and power. NY: Cambridge University Press.

Beck, U. (1992). Risk society: Towards a new modernity. Thousand Oaks, CA: Sage Publications.

Bereiter, C. (1994). Constructivism, socioculturalism, and Popper's world 3. Educational Researcher, 23 (7), 21-23.

Berry, W. (1977). The unsettling of America: Culture and agriculture. San Francisco: Sierra Club Books.

Berry, W. (1990). What are people for. New York: North Star Press.

Bird, E. (1987). The social construction of nature: Theoretical approaches to the history of environmental problems. Environmental Review, 2 (4), 255-264.

Birkenholz, R., Frick, M., Gardner, H., & Machtmes, K. (1994). Rural and urban inner-city school student knowledge and perception of agriculture. Proceedings of the Twenty-First National Agricultural Education Research Meeting, 130-136.

Busch, L., Lacy, W., Burkhardt, J., Hemken, D., Moraga-Rojel, J., Koponen, T., & de Souza Silva, J. (1995). Making, nature, shaping culture: Plant biodiversity in global context. Lincoln: University of Nebraska Press.

Busch, L., Lacy, W., Burkhardt, & Lacy, L. R. (1991). Plants, power and profit: social, economic, and ethical consequences of the new biotechnologies. London: Basil Blackwell.

Carlsen, W. S. (1991). Effects of new biology teachers' subject-matter knowledge on curricular planning. Science Education, 6, 631-647.

Cazden ,C. (1988). Classroom discourse. Portsmouth, NH: Heinemann Educational Books, Inc.

Christoff, P. (1996). Ecological citizens and ecologically guided democracy. In Brain Doherty & Marius de Geus, (Eds.), Democracy and green political thought: Sustainability, rights and citizenship. London: Routledge.

Dewey, J. (1916). Democracy and Education. New York: Macmillian Publishing Co.

Dewey, J. (1933). How we think. New York: D. C. Heath and Company.

Donnelly, J. F. (1992). Technology in the school curriculum: A critical bibliography. Studies in Science Education, 20, 123-156.

Douherty , B. & de Geus, M. (1996). Democracy and green political thought: sustainability, rights and citizenship. London: Routledge.

Driver, R. Guesne, E., & Tiberghien, A. (1985). Children's ideas in science. Buckingham, UK: Open University Press.

Driver, R., Asoko, H., Leach,J, Mortimer, E., & Scott, P. (1994). Constructing knowledge in the classroom. Educational Researcher, 23 (7), 5-12.

Eggertsson, T. (1990). Economic behavior and institutions. Cambridge: Cambridge University Press.

Erickson, F. (1986). Qualitative Methods. In M. Whittrock (Ed.), Research in teaching and leaning, Vol. 2. New York: Macmillan Publishing Co.

Feenburg, A. (1995). Subversive rationalization: technology, power and democracy. In A. Feenburg & A. Hannay (Eds.), Technology & the politics of knowledge. Bloomington: Indiana University Press.

Feyerabend, P. (1978). Science in a free society. London: NLB.

Fine, G. (1990). Symbolic interactionism in the post-Blumerian age. In G. Ritzer (Ed.), Frontiers of social theory. New York: Columbia University Press.

Flood, R., & Elliot, J. (1993). Agriculture awareness in Arizona. Proceedings of the twenty -first national agricultural education research meeting, 103-111.

Frake, C. (1980). Language and cultural description. Palo Alto, CA: Stanford University Press.

Frank, R. (1987). Microeconomics and behavior. 3rd ed. New York: McGraw Hill.

Frick, M., Birkenholz, R. & Machtmes, K. (1995). Rural and urban adult knowledge and perceptions of agriculture. Journal of Agricultural Education, 36 (2), 44-53.

Frick, M., Kahler, A., & Miller, W. (1991). A definition and the concepts of agricultural literacy. Journal of Agricultural Education, 32 (2), 49-57.

Frick, M., & Spotanski, D. (1990). Coming to grips with agricultural literacy. The Agricultural Education Magazine 62 (8), 6-13.

Frick, M., & Wilson, D. (1996). Native American high school student knowledge and perception of agriculture. Proceedings of the twenty-third national agricultural education research meeting, 59-65.

Foster, T. (1992a). Technology education research: Looking to the future. The Technology Teacher, 52 1, 33-34.

Foster, T. (1992b). Topics and methods of recent graduate student research in industrial education and related fields. Unpublished report.

Gardner, H. (1991). The unschooled mind: How children think and how schools should teach. NY: Basic Books.

Gazzaniga, M. (1985). The social brain. NY: Basic Books.

Gee, J. (1991). What is literacy? In C. Mitchell & K. Weiler, Culture and the discourse of the other. NY: Bergin and Garvey.

Goodman, D., & Redclift, M. (1991). Refashioning nature: Food, ecology, and culture. New York: Routledge.

Green, K. (1992). Creating demand for biotechnology: shaping technologies and markets, In Coombs, R. Saviuotti, P., Walsh, V. (Eds.), Technological change and company strategies (pp. 164-184). London, Academic Press.

Gussow, J. (1983). Food wanting, needing and providing. Food Monitor, 34, 12-15.

Gussow, J. (1991). Chicken Little, Tomato Sauce & Agriculture. New York; The Bootstrap Press.

Hennen, L. (1995). Discourses on technology: public debates on technology and technology assessment as symptoms of reflexive modernisation. In R. von Schomberg (Ed). Contested technology: ethics, risk and public debate. International Centre for Human and Public Affairs: Tilurg, The Netherlands.

Hikawa, H., & Trexler, C. (in press). Developing a process for an agriculturally-based curriculum for elementary and middle school: A case of teacher struggle in Countryside Charter School. Proceedings of the twenty-sixth annual national agricultural education research conference.

Hogan, K., & Fisherkeller, J. (1996). Representing students' thinking about nutrient cycling in ecosystems: Bidimensional coding of a complex topic. Journal of Research in Science Teaching, 3 (9), 941-970.

Humphrey, J., Stewart, B., & Linhardt, R. (1994). Preservice elementary education majors' knowledge of and perceptions toward agriculture. Journal of Agricultural Education, 35 (2), 27-30.

Jennings, B. (1986). Representation and participation in the democratic governance of science and technology. In M. Goggin (Ed.), Governing science and technology in a democracy. Knoxville: The University of Tennessee Press.

Jonassen, D., Beissner, K., & Yacci, M. (1993). Structural knowledge. Hilldale, NJ: Lawerance Erlbaum Associates, Inc.

Kuhn, T. (1962). The structure of scientific revolutions. IL: The University of Chicago Press.

Kunreutner, H. & Slovic, P. (1978). Economics , psychology and protective behavior. American Economic Review, 68: 64-69.

Latour, B. (1987). Science in action. Cambridge, MA: Harvard University Press.

Law, D. (1990). Implementing agricultural literacy programs. The Agricultural Education Magazine, 62 (9), 5-6, 22.

Leising, J., & Zilbert, E. (1994). Validation of the California agriculture literacy framework. Proceedings of the twenty -first national agricultural education research meeting, 112-119.

Levenstein, H. (1988). Revolution at the table: The transformation of the American diet. New York: Oxford University Press.

Mannheim, K. (1929). In L. Wirth & E. Shils (Trans.), (1936) Ideology and utopia: An introduction of the sociology of knowledge. New York: Harcourt Brace Jovanovich Publishers.

Margolis, H. (1987). Patterns, thinking and cognition. Chicago, IL: University of Chicago Press.

Marris, P. (1974). Loss and change. New York: Pantheon Books.

Merton, R., Fiske, M., & Kendall, P. (1952). The focused interview: A manual of problems and procedures. Glencose, IL: The Free Press.

Michals, S., & O'Connor, M. (1990). Literacy as reasoning within multiple discourses: implications for policy and educational reform. Paper presented at the Council of Chief State School Officers 1990 Summer Institute.

Miles, M., & Huberman, A. (1994). Qualitative data analysis: An expanded sourcebook (2nd ed.). Thousand Oaks, CA: Sage Publications.

Moll, L. (1990). Vygotski and education: instructional implications and applications of soci-historical psychology . New York: Cambridge University Press.

National Council for Agricultural Education. (1999). A new era for agricultural education: Reinventing agricultural education for the year 2020. Alexandria, VA: Author.

National Research Council. (1988). Understanding agriculture: New directions for education. Washington, D.C.: National Academy Press.

Novack, J. (Ed.). (1983). Proceedings of the first international seminar on misconceptions and educational strategies in science and mathematics. Ithaca, NY: Cornell.

Novack, J., & Gowin, D. (1984). Learning how to learn. NY: Cambridge Press.

Piaget, J. (1950). Psychology of intelligence. London: Routledge and Kegan Paul.

Piaget, J. (1957). Language and throughout from a genetic point of view. In Elkind, D., Six psychological studies. New York: Vintage Books.

Pigou. A. C. (1932). The economics of welfare (4th ed.). London: Macmillan.

Posner, G., & Gertzog, W. (1982). The clinical interview and the measurement of conceptual change. Science Education, 66, 195-209.

Posner, G., Strike, K., & Gertzog, W. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. Science Education, 66, 211-227.

Raizen, S., & Michelson, A. (1994). The future of science in elementary schools. Washington, D.C.: National Center for Improving Science Education.

Redclift, M. (1987). Sustainable development: Exploring the contradictions. London: Routledge.

Resnick, L. B. (1987). Learning in school and out. Educational Researcher, 16 (4), 13-19.

Rosebury, A., Warren, B., & Conant, F. (1992). Appropriating scientific discourse: Findings from language minority classrooms. The Journal of the Learning Science, 2 (1), 61-94.

Rouse, J. (1987). Knowledge and power: Toward a political philosophy of science. Ithica, NY: Cornell University Press.

Russell, E., McCracken, D., & Miller, W. (1990). Position statement on agricultural literacy. The Agricultural Education Magazine 62 (9), 13-14, 23.

Samuels W., & Schmid, A. (1997). The concept of cost in economics. In Samuels, Medema, & Schmid (Eds.), The economy as a process of valuation.

Saunders, P. (1995). Capitalism. Minneapolis, MN: University of Minnesota Press.

Scharzweller, H. & Lyson, J. (1995). Research in rural sociology and development: Sustaining agriculture and rural communities, Vol. 6. Greenwich, CT: AI Press.

Schmid, A. (1998). Introduction of Institutional and Behavioral Theory. Unpublished manuscript.

Schmid, A. (1987). Property, power & public choice: An inquiry into law and economics. New York: Praeger Publishers.

Schriffin, D. (1994). Approaches to discourse. Cambridge, MA: Blackwell Publishers, Inc.

Sen, A. (1982). Choice, welfare and measurement. Oxford, UK: Basil Blackwell.

Simon, H. (1957). Models of man: social and rational; mathematical essays on rational human behavior in society. New York: Wiley.

Simon, H. (1986, November-December). The Failure of Armchair Economics. Challenge, 18-25.

Simon, H. (1987). Rationality in psychology and economics. In Robin Hogarth and M. Reder (Eds.), Rational choice. University of Chicago Press.

Smith, E. (1990). A conceptual change model of learning. In S. Glynn, R. Yeany, & B. Britton (Eds.), Psychology of Learning Science. Hillsdale, NJ: Lawrence Erlbaum.

Stemerding, D. (1995). The entrenchment of human genome technology in society: On shifting boundaries between private and public discourses. In R. von Schomberg (Ed), Contested technology: ethics, risk and public debate. International Centre for Human and Public Affairs: Tilurg, The Netherlands.

Tannen, D. (1989). Talking voices: Repetition, dialogue, and imagery in conversational discourse. Cambridge, MA: Cambridge University Press.

Terry, R., Herring, D., & Larke, A. (1992). Assistance needed for elementary teachers in Texas to implement programs of agricultural literacy. Proceedings of the twenty-first national agricultural education research meeting, 233-240.

Thompson, P. B. (1995). The spirit of the soil: Agricultural and environmental ethics. New York: Routledge.

Trexler, C. (1997). The cheeseburger came from where?: Elementary students' understanding of how food is affected by biology and climate. Proceedings of the twenty-fourth national agricultural education research meeting, 23-33.

Trexler, C. (1997). Synthesis of Project 2061 Benchmarks for agriculture and the California Agriculture Literacy Framework. Unpublished framework.

Trexler, C. (1998). The cheeseburger came from where?: Elementary students' thoughts about and understandings of the technological origins of food. Proceedings of the fifty-second annual central region research conference and seminar in agricultural education, 89-99.

Trexler, C., & Miller, N. (1992). Improving scientific literacy through an agriscience curriculum. The Agricultural Education Magazine, 65 (4), 14-16, 23.

Trexler, C., & Suvedi, M. (1998). Perceptions of agriculture as a context for elementary science teaching: A case of change in Sanilac county, Michigan. The Journal of Agricultural Education, 39, 4, 28-36.

Vellom, R. Anderson C, and Palincsar, A. (1993). Scientific Reasoning in School Contexts. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching. Atlanta GA.

Vygotski, L. (1962). Thought and language. Cambridge, MA: MIT Press.

Warren, S. (1989, August). The Legal-Economic Nexus. The George Washington Law Review, 57, 6.

Weber. M. (1958). The Protestant ethic and the spirit of capitalism. New York: Charles Schribner's Sons.

West, L, Fensham, P., & Garrard, J. (1985). Describing the cognitive structures of learners following instruction in chemistry. In L. West & A. Pines (Eds.), Cognitive structure and conceptual change. N Y: Academic Press.

Wilkins, L. (1995). Seasonal and local diets: Consumers' role in achieving a sustainable food system. In Research in rural sociology and development: Sustaining agriculture and rural communities, Vol. 6. Greenwich, CT: AI Press, Inc.

Williamson, O. (1989). Transaction cost economics. In Schmalensee & Willig (Eds.). Handbook of industrial economics. Dordrecht: North Holland

Winner, L. (1995). Citizen Virtues in a Technological Order. In A. Feenburg and A. Hannay (Eds.) Technology & the politics of knowledge. Bloomington: Indiana University Press.