A QUALITATIVE STUDY OF PROSPECTIVE ELEMENTARY TEACHERS' GRASP OF AGRICULTURAL AND SCIENCE EDUCATIONAL BENCHMARKS FOR AGRICULTURAL TECHNOLOGY

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Abstract

The purpose of this qualitative study was to determine the level of understanding that prospective elementary teachers possess about biotechnology in agriculture. Based on the constructivist approach to learning and research, respondents' understanding of two nationally defined technology-focused educational benchmarks in agriculture was determined. Data analysis included validating benchmarks and language that guided discourse, generating conceptual proposition maps, coding responses for comparison with expert propositions, and interpreting confirming or disconfirming patterns among informants. Informants who grew up in rural areas demonstrated a more complex understanding of the trade-offs inherent in agricultural technology, while those from urban backgrounds indicated the most concern over ethical dilemmas. Pollution of the environment as a result of pesticides was the most completely understood concept. Conversely, the informants lacked understanding concerning human manipulation of plants and animals to produce desired characteristics. Prospective teachers in this study did not possess requisite understandings to help elementary students gain knowledge and understandings of, or concern for the trade-offs found in the use of agricultural biotechnologies.

Introduction

As the number of people directly involved in agriculture has decreased, the general public's basic understanding of the food and fiber industry has declined. This dearth of understanding may be due in part to a lack of interest in agricultural issues (Weiss, 1999). Now that biotechnology has caused "a revolution that is pushing society into rethinking what we want out of agriculture" (Johnson, 1999); however, an increasing number of consumers want to know about these new technologies and their effects. Concerns over food safety, environmental conservation, and agricultural sustainability are issues that have come to the fore.

Two sides emerge from the biotechnology debate. One side believes biotechnology to be a threat to the environment and cites studies to support its claims. For instance, Johnson, (1999) described how cross-fertilization from genetically modified plants to natural species could potentially create entire pastures of herbicide-resistant grasses, which could negatively affect other species of plants and animals. An actual situation that mirrors the scenario described above was the discovery of Starlink™ Bt corn in Taco Bell™ taco shells. This bio-engineered corn was only approved for animal feed, not human consumption (Environmental Protection Agency, 2000), yet it was found in the human food supply. Such potential and current problems erode public trust in policy makers that protect the food supply (Hennen, 1995).

On the other side of the debate are advocates who support biotechnology based on its benefits. They argue that biotechnology reduces herbicide use, increases yields, adapts plants to the environment instead of the environment to the plant, produces healthier foods, and decreases disease. They respond to those who believe that biotechnology and genetically modified crops will destroy sustainable agriculture by saying just the opposite. Johnson (1999) has argued that in its present form "intensive agriculture…is probably not sustainable" (p. 132) and that biotechnology decreases the negative environmental impact. He stated that " …although the *levels of production* may be sustainable…the *social, environmental, and economic consequences* …may not be sustainable…." (p.132) [emphasis added by original author]. The debate between supporters and opponents of biotechnology will continue because of fundamental philosophical differences and because the technology is too new to fully understand the long term costs and benefits to human health, safety and the environment.

Most will agree, no matter which side of the debate they are on, that this new technology is not without risks, and that with these risks also come benefits. Betsch (1996) and Weiss (1999) have argued the public needs to be informed of both risks and benefits in order to form a personal opinion on biotechnology. van Duijn (1995) argued that ultimately the public would decide what technologies will be used and which will stay on the drawing board. In order for the public to make informed decisions their "opinions must be based on a proper sensitivity to and knowledge and understanding of the issues " (Ingram, 1992).

Education can foster public understanding of biotechnology. Scientists agree that education is the key to the continuation or the demise of the use of biotechnology (Betsch, 1996; Ingram, 1992; Weiss, 1999). Ingram (1992) contended that education should not only be directed to the adult public but also at primary school children, because they are future consumers. In order to educate children, however, elementary school teachers need to possess understandings of basic scientific and technological principles undergirding biotechnology (AAAS, 1993). A reasonable way to bring relevance to biotechnology is through the food children eat and the fiber they use. Agriculture and science educators agree and have included agri-food systems concepts in national curricular standards and benchmarks (AAAS, 1993; Leising & Igo, 1998).

This study's theoretical framework is based on constructivist theory. Constructivists believe that learning is a process of building meaning (Merriam & Caffarella, 1999). In this case, meaning is used to describe the sense making process people undergo as they struggle to understand. Early constructivist theory was based on Piaget's (1952) work with children, which was later used to describe the process of learning more generally.

In science education, researchers have taken Piaget's work further and developed the theory of conceptual change. The notion of conceptual change is that all people build mental constructs, or schema that allow them to integrate new ideas and experiences into preexisting mental frameworks to aid with the sense making process. At times, preexisting frameworks can be so robust that they inhibit a person's ability to assimilate and accommodate new ideas, experiences, and concepts into a modified framework based on alternative perspectives. By comparing learner conceptions (built by connecting schema) with those of experts, researchers have determined the accuracy of idiosyncratic understandings (Driver, Guesne & Tiberghien, 1985).

An initial step in this type of research is to unearth and make apparent learner schema related to complex understandings. By comparing the schema of various people, researchers have identified commonly held naive or misconceptions that may hinder the construction of new schema that more closely resemble expert conceptions (Glynn, Yeany, & Britton, 1991). By determining commonly held conceptions among groups, curriculum and educational programs can be tailored to meet the needs of learners. This line of research has direct implications for agricultural education, because researchers presently know little about the idiosyncratic understandings that constitute agri-food system literacy. Agricultural education researchers have not yet defined the cognitive structures that build a foundation for literacy. This study has direct utility in unraveling what prospective teachers understand about biotechnology.

Purpose/Objectives

The purpose of this qualitative study was to determine what eight prospective elementary teachers understood about agricultural and science education national curricular benchmarks related to the agri-food system. More specifically, this study sought understandings of 9th-12th grade level benchmarks related to technologies in agriculture and their effects on human culture and the environment. The objectives of this study were: (1) to determine informants' backgrounds, and (2) to compare prospective elementary teacher understandings with expert understandings for the role of science and technology in the agri-food system.

Methods/Procedures

In agricultural education, abundant knowledge and positive perceptions gleaned through survey research are often equated with literacy. Frick and Wilson (1996) have suggested, however, that one's literacy involves, not simply a cache of facts, but "a basic understanding of agriculture" (p. 59). To gain firm evidence of understanding, the researchers employed a qualitative protocol for inquiry that combined grounded theory (Strauss & Corbin, 1990) and cognitive anthropology (Hamilton, 1994) so as to propose theory about what prospective teachers understand about technology benchmarks. This methodology—although new to agricultural education research—has been used by science education researchers for nearly two decades (Posner, Strike, & Gertzog, 1982; Smith, 1991) and complements previous scholarship in agriculture literacy for our profession.

The population for this study included eight purposefully selected prospective elementary teachers who were of either junior or senior standing in college. Selection was based on educational background. Students were sought who had little university science coursework, because they were representative of most elementary educators (Fortenberry & Powlik, 1998; Zembal-Saul, Blumenfeld, & Krajcik, 2000); however, one participant minored in science.

To ground the interviews in previous scholarship, the researchers developed a synthesis of technology educational benchmarks from the disciplines of science (American Association of the Advancement of Science, 1993) and agricultural education (Leising & Igo, 1998). Members of a land-grant university's Science Education and Agricultural Education departments reviewed interview prompts and the research protocol. Clinical interviews were used to surface informant understandings of the benchmarks. In each 45-minute interview, approximately five minutes were spent determining demographic background; the remaining time probed student understanding of benchmarks. These videotaped and transcribed interviews served as the primary data sources. Secondary data consisted of the researchers' field notes and any materials generated by the interviewees. These materials included informant-developed notes used to organize their ideas prior to the interview.

Two different strategies were used to analyze data. First, demographic information was reported descriptively. The second strategy used Hogan and Fisherkeller's (1996) technique for representing highly complex thinking to ascertain understandings of technology benchmarks. A bimodal coding scheme was used to represent student thinking. The sophistication of thought was judged by comparison with expert propositions for sub concepts along two dimensions: quality (compatibility) and depth (elaboration). Analysis of data involved four phases. First, the researchers developed expert propositions based on the science and agricultural education benchmarks. Science and Agricultural Education faculty reviewed the propositions for accuracy. With this feedback, expert propositions and goal conceptions were developed. Table 1 lists the key concept, benchmarks, and language needed for discourse. Following this table is Table 2 that provides expert definitions for the 9-12th grade benchmarks.

Table 1
Benchmarks for Science and the Food and Fiber System Literacy Framework

Key Concepts	Benchmark	Language
A. What is the role of science and technology in the food and fiber system?	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, seed stock
B. How has the modern agri-food system impacted society?	Describe trade-offs inherent in the use of agricultural technology in terms of environment and human culture.	production, pesticides, sustainability, loss of culture, fertilizers, employment, pollution

Table 2
Expert Conceptions

Benchmark 1: Engineering of farm plants and animals.
Humans engineer plants and animals to produce characteristics they value. Most often this comes in the form of greater productivity, e.g. yield per acre, disease or pest resistance in plants, or feed efficiency or carcass yield in livestock. The designing of plants and animals by humans for specific characteristics is not new. Humans have selected plant and animal seed stock with desired qualities for thousands of years. They breed these superior animals to other animals in an attempt to improve specific, desired characteristics. Today, however, humans—with the use complex technologies— have 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, and embryo and gene transfer. The use of these technologies has the potential to increase output of both farm plants and animals, but also pushes the limits of acceptability by some in society.
Benchmark 2: 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 to 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 often to increase efficiency and reduce time and labor inputs in all aspects of the agri-food system. By doing so, human culture is altered. Society becomes dissociated from the land as population shifts from rural to urban areas. 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 comes 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 sites—to maximize economies of scale—there is greater chance that the effects of microbial contamination would spread quickly throughout a large geographic region. Finally, the industrialized agri-food system is dependent upon petroleum for its operation—tractors, inorganic fertilizers, pesticides, transport, storage, 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.

In the second phase of analysis, raw data from student interview tapes were analyzed by generating conceptual proposition maps. These maps served as summary portrayals of prospective teacher thinking for each benchmark. Maps were verified for accuracy by comparing them repeatedly with primary data sources (interview tapes) and with the secondary data sources (field notes and products developed by informants such as graphic organizers and notes). Each tape was viewed a minimum of four times.

This "persistent observation" helped the researchers verify the trustworthiness and credibility of interpretations (Lincoln & Guba, 1986). To ensure confirmability (Guba & Lincoln, 1989), another researcher familiar with the research protocol coded data with 99% agreement with the primary researcher.

Phase three focused on coding prospective teachers' responses. The sophistication of thinking was judged by comparison with expert propositions. Informants' understandings were coded based on this scheme (Table 3).

Table 3
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 lacks 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 do 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 & Huberman, 1994). This was accomplished by two procedures. First, each benchmark was analyzed across individuals. Second, holistic portraits of informant thinking were analyzed to ascertain how understanding of sub-concepts might influence other benchmarks. Patterns within the data were ascertained by comparing across individuals.

Findings/Discussion

Research Objective One: Background of prospective elementary teachers

Objective one focused on prospective elementary teacher background. The eight informants included three males and five females of white, European ancestry. Their schooling varied with two having attended Catholic school, while the others attended public school before college. All informants attended a land-grant university and majored in elementary education, but had various minors. Place of origin was not a selection criteria, however, three students came from rural backgrounds, three from the suburbs, and two from a major metropolitan city. Occupations of their parents varied. Table 4 displays prospective teachers' backgrounds.

Table 4
Background of Prospective Teacher Informants

Name	Gender	Ethnicity	School Background	Raised	Parents' Occupation
Sid	Male	European American	Public School El Ed, Social Studies	Suburb	Father - Electrician
Kat	Female	European American	Public School El Ed, English	Suburb	Mother - Teacher Father - Landscape architect
Molli	Female	European American	Catholic School El Ed, Special Ed	City	Mother - Pre-school teacher Father - Teacher
Kara	Female	European American	Catholic School El Ed, English	Rural	Father - Farmer
Di	Female	European American	Public School El Ed, English	City	Father - Detroit civil servant
Dan	Male	European American	Public School El Ed, Agriscience	Rural	Father - Hardware store owner
Guy	Male	European American	Public School El Ed, Social Studies	Suburb	Father - Janitor Mother - Sales clerk
Meri	Female	European American	Public School El Ed, Social Studies	Rural	Mother - Real estate agent

Research Objective Two: Prospective teacher understandings of technology related benchmarks

The second research objective focused on prospective elementary teacher understandings of benchmarks related to (1) engineering of plants and animals to produce new characteristics, and (2) trade-offs of agriculture technology in terms of the environment and humans. In this section, the sub-concepts necessary to understand benchmarks are displayed along with prospective teacher compatibility with expert conceptions.

Benchmark One. Describe how new varieties of farm plants and animals have been engineered to produce new characteristics

Table 5 illustrates prospective teacher understandings of the role of science and technology play in the agri-food system.

Note bullets indicate informants' discourse was elaborate and compatible with expert's sub-concepts.

Table 5
Prospective Teacher Understanding of Science and Technology's Role in the Agri-food System

Benchmark	Sid	Kat	Molli	Kara	Di	Dan	Guy	Meri
1) Selection of desired characteristics								
a) cloning	•	•						•
b) selective breeding	•	•		•				•
c) cross breeding				•				
d) gene transfer								
Coding	$CS^{+2/4}$	$CS^{+2/4}$	N	$CS^{+2/4}$	N	Ø	N	$CS^{+2/4}$

ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy; CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate
Superscript indicates depth of understanding of sub concepts.

Sid, Kat, Kara and Meri were coded Compatible-Sketchy and understood that humans selected desired traits in farm plants and animals and then employed strategies/technologies to produce these valued characteristics. They mentioned reproductive techniques, such as selective breeding of seed stock, 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 displayed her understanding of selective breeding, while bringing to the fore her concern over cloning. Note, however, that her understanding about fat in meat (marbling) is inaccurate. Cattle, in most cases, are actually selected for less external fat and more intramuscular fat.

Meri- I know Angus beef is supposed to be the best.
Interviewer- Do you have any idea why?
M- Well they're supposed to be corn fed. They're supposed to have less fat in their meat. Just a better type of cow I guess. Probably genetically bred 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 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- Can you think of any disadvantages?
M- Yeah, 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- 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- 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, eventually, I don't know. It could eventually 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 believed that there were differences between these two types of cattle, and rightfully so, but she didn't know how they got that way. She didn't see the connection between these animals and the humans who bred, and continue to design and breed, these animals for the traits they value. Di stated:

I- So, are there differences between the dairy ones and the meat ones [she was discussing dairy and beef cattle]?
D- I think that they are both capable of producing milk, but I think that the dairy cows produce more milk.
I- How?
D- 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.
D- I'm trying to think about what I can compare it to. I think there is like a different breed of cow; I guess.
I- How did they get that way?
D- Um, I don't know. [Laughs], I don't know.
I- You talked about a line of cow, tell me about that.

D- Still the same sort of concept. I'm not sure how they got that way, but I think.
I- How do they stay that way?
D- Well, I was under the impression that dairy cows, once you start milking them, that if you don't milk them, 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 milk them [laughs].

Table 6 shows that most informants, with the exception of Sid and Di, articulated a Compatible-Sketchy understanding of the environmental aspect of the expert conception. The conception included: (a) altering the physical and biological world to maximize output of selected organisms (limiting diversity-mono-cropping) and promoting the use of an unsustainable agri-food system based on non-renewable resources, and (b) increasing changes caused by externalities (polluting the environment) from production.

Table 6
Prospective Teacher Understanding of the Impacts of the Modern Agri-food System on Society

Benchmarks	Sid	Kat	Molli	Kara	Di	Dan	Guy	Meri
1) Environment								
a) sustainability	•							
b) pollution	•	•	•	•		•	•	•
Coding	$CE^{+2/2}$	$CS^{+1/2}$	$CS^{+1/2}$	$CS^{+1/2}$	N	CS^{+1}	$CS^{+1/2}$	$CS^{+1/2}$
2) Human Culture								
a) labor	•	•		•	•	•	•	•
b) population shift	•	•		•	•	•		•
c) dependency on machines/science	•	•	•	•	•	•	•	•
Coding	$CE^{+3/3}$	$CE^{+3/3}$	$CS^{+1/3}$	$CE^{+3/3}$	$CE^{+3/3}$	$CE^{+3/3}$	$CS^{+2/3}$	$CE^{+3/3}$

ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy; CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate
Superscript indicates depth of understanding of sub concepts.

Benchmark Two: Describe trade-offs inherent in the use of agricultural technology in terms of environment and human culture

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 (profitable) plants and animals for production, thus reducing sustainability. 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- 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 it 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. 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 seeps into it. 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.

I- So why would it be a big deal if there were pesticides on that lettuce or 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, if I'm not getting cancer from it or something like that, I'm OK. Some people are just real careful about what they put in their bodies, and I guess they rightly can be.

I- Any other trade-offs?

K- I know they use pesticides on a day that's not so windy, but because it's a pesticide it might get into the water. It will be in the soil, so it might filter through and get in the water somehow.

Prospective teachers articulated a deeper understanding of technological trade-offs on human culture than they did for the environment. Six informants understood all three parts of the goal conception which included technological trade-offs in: (1) labor resulting in less time required for food production and preparation, and an increase in urban culture; (2) population shifts resulting in a decline of rural culture and a disconnection from the land; and (3) dependency on machines and science resulting in greater productivity, misunderstanding and fear. As indicated in Table 6, Sid, Kat, Kara, Di, Dan and Meri were coded as Compatible-Elaborate because they understood all three parts of the goal conception.

Compatible-Sketchy codings were assigned to Molli and Guy. Both indicated that humans had become dependent on agricultural technologies and that there were risks associated with their use. They did not articulate, however, an understanding of society's loss of rural culture and of city dwellers' disconnection from the land. In addition, Molli did not talk about the timesavings that resulted from agricultural technology. Guy's response indicated he did not understand the population shift resulting from use of technology.

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.

Conclusions/Implications

Although codings were similar among informants raised in suburban and rural areas, those who grew up in rural areas demonstrated the more compatible and elaborate discourse relative to the cultural trades-offs inherent in the use of agricultural technology. Because of coding scheme limitations and the amount of space available to report raw data, informant discourse that would make these differences apparent could not be included. The informants raised in urban areas were less balanced in their understanding and spoke more wearily of trade-offs. Generally, as a group, those from suburbs and cities also spoke more about the detrimental effects of these technologies than they did about the benefits.

Informants' sketchy conceptions seemed to be the result of missing sub-concepts that could be built by additional exposure to specific knowledge and ideas associated with agri-food system technologies and its structure. This supports, Trexler's (2001) conclusion that understanding of sub-concepts was necessary for elementary students to comprehend the complexities of other agri-food system concepts. Informants possessed clearer and deeper understanding of technology's impact on humans in a general way, but less understanding of the specific agri-food system technologies.

Generally informants spoke more elaborately about negative aspects of agri-food technologies than they did benefits. In other words, this study's prospective teachers had constructed cognitive structures that were primarily based on a fear of pesticides and the pollution that they had heard these technologies cause. On the other hand, the majority had incomplete or nonexistent understanding of how humans engineer plants and animals to produce desired characteristics, e.g. gene transfer. This is noteworthy because biotechnology advocates suggest such technologies can potentially decrease the use of chemicals that pollute the environment—the same chemicals that these prospective teachers so gravely feared. So, these prospective teachers feared pesticides, but did not have an awareness of other emerging technologies that some promise will reduce the use of pesticides in farming.

Prospective teachers were keenly aware that technologies (pesticides) sometimes polluted the environment, and all but one informant had no schema for the concept of agri-food system sustainability. It seemed these prospective teachers were not well enough informed to assess the risks and benefits of new agricultural technologies. This supports biotechnologists' (Betsch, 1996; Weiss, 1999) contention that people lack adequate knowledge and understandings necessary to make informed decisions with regard to biotechnology.

In contrast, informants accessed well-developed schema and spoke knowledgeably about the impact of industrial technologies on human culture in terms of reduction of manual labor in agriculture production, population shifts away from rural areas and to cities, and human dependency on machines and science. It seemed that these "social studies" based ideas had been well integrated into the schema of these prospective teachers.

Further research can yield greater insight into what prospective teachers understand about technologies used in the agri-food system. Specifically, additional use of this study's research protocol by other researchers on similar, but different groups, could add to the transferability of findings (Guba & Lincoln, 1989). Transferability refers to comparing contexts from one situation to other similar situations; it is akin to generalizability in quantitative research. These studies might target areas where non- and misconceptions are present.

This study underscores the need for an enhanced curriculum for these prospective teachers because they do not understand concepts at the very foundation of agri-food system literacy. If teachers lack these concepts, they are unable to create learning opportunities that make content more comprehensible to children, thereby limiting students' ability to learn content in meaningful ways (Zembal-Saul, Blumenfeld, & Krajcik, 2000). Acquiring agri-food system understandings, however, is not an easy task. Mascarenhas (1997) has argued that weighing the risks and benefits of technologies is especially difficult because it encompasses not only science, but ethics and economics as well. Therefore, to help prospective teachers grasp these complex understandings, science and social science methods courses may consider emphasizing the integration of ethical and scientific content related to agricultural technologies.

Without this background, prospective teachers will not be prepared to help students gain the requisite knowledge, understandings, or concern to participate in public discourse about the use of agri-food system technologies. As tension over biotechnology use comes to the forefront, Dewey (1916) reminds us that public education's role is to help society readjust institutions to meet the values of the majority through the democratic process. It is noteworthy that teachers in this study did not have the conceptual understandings necessary to carry out their role in public education with regard to agri-food system technologies.

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