Prospective Elementary Teachers' Understandings Of Agricultural Technology and Its Effects on Culture And The Environment

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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 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 that 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.

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). However, now that biotechnology has caused "a revolution that is pushing society into rethinking what we want out of agriculture" (Johnson, 1999, p.131), 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 need to be addressed.

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 effect 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, p.94).

Despite some setbacks, biotechnology advocates support their claims based on the potential benefits this technology offers. 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]. It is obvious that the debate between supporters and opponents of biotechnology will continue.

Most will agree, no matter which side they are on, that this new technology is not without risks, but with these risks also come benefits. Betsch (1996) and Weiss (1999) argued that the public needs to be informed of both risks and benefits in order to form a personal opinion on biotechnology. Ultimately, the public will decide what technologies will be used and which will stay on the drawing board (van Duijn, 1995). 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, p.123).

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. A reasonable way to bring relevance to biotechnology is through the food we eat and the fiber we use. Agriculture and science educators agree and have included agri-food systems concepts in the curricula (American Association for the Advancement of Science, 1993; Leising & Igo, 1998).

This study focuses on determining the extent and depth of prospective elementary teachers' understandings of ninth through twelfth grade benchmarks that deal with the science and technology of agriculture. The researchers examined understanding of the trade-offs of technology and how humans alter plants and animals to produce the characteristics they value. Understandings of such concepts are constructed through experiences at the individual level. Therefore, 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 which 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 by comparing learner conceptions (built by connecting schema) with those of experts to determine the accuracy of idiosyncratic understandings (Driver, Guesne & Tiberghien, 1985). The ultimate goal of much of this research was to unearth and make apparent learner schema related to complex understandings. By comparing multiple learner understandings, researchers have identified naive or misconceptions that may hinder the construction of new schema that more closely resemble expert conceptions (Glynn, Yeany, & Britton, 1991). 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 understand about agricultural and science education national benchmarks related to the agri-food system. More specifically, this study sought understandings of benchmarks related to technology in agriculture and its 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 compliments 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. Prospective teacher selection was based on educational background. Students were sought who had little university science coursework, because they are 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.

In this study 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 subconcepts 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.

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, seedstock production,
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.	sustainability, loss of culture pesticides, fertilizers, employment, pollution,

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). 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 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 2).

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. And second, holistic portraits of informant thinking were analyzed to ascertain how understanding of subconcepts might influence other benchmarks. Patterns within the data were then ascertained by comparing individuals.

Table 2

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.

Findings/Discussion

Research Objective 1: 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 3 displays prospective teachers' backgrounds.

Table 3

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 2: 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 subconcepts necessary to understand benchmarks are displayed along with prospective teacher compatibility with expert conceptions.

***Benchmark 1. Describe how new varieties of farm plants and animals have been engineered to produce new characteristics*.**

Table 4 illustrates prospective teacher understandings of the role of science and technology in the agri-food system.

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

Table 4

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}	CS^{+2}	N	CS^{+2}	N	Ø	N	CS^{+2}

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 subconcepts.

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 displayed her understanding of selective breeding, while bringing to the fore her concern over cloning:

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 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, 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 just think that there is sort of 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 a little bit about a line of cow, well, 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 5 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) and promoting the use of an unsustainable agri-food system based on non-renewable resources, and (b) increasing changes of externalities of production by polluting the environment.

Table 5

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}	CS^{+1}	CS^{+1}	CS^{+1}	N	CS^{+1}	CS^{+1}	CS^{+1}
2) Human Culture								
a) labor	•	•		•	•	•	•	•
b) population shift	•	•		•	•	•		•
c) dependency on machines/science	•	•	•	•	•	•	•	•
Coding	CE^{+3}	CE^{+3}	CS^{+1}	CE^{+3}	CE^{+3}	CE^{+3}	CS^{+2}	CE^{+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 subconcepts.

Benchmark 2. 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 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 effects 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 like if that was the only thing in your diet.

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 5, 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 technology and that there were risks associated with its 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 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] effected 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

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. 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.

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 researchers on similar, but different groups, for example, can add to the particularizability of findings (Erickson, 1986). Particularizability refers to the taking of particulars from one situation and comparing them 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'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 no understanding of other technologies, such as gene transfer in plants and animals, that biotechnology advocates suggest can decrease the use of chemicals that pollute the environment—the same chemicals that these prospective teachers so gravely feared. It appeared that 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.

This study underscores the need for an enhanced curriculum for prospective teachers because they lack what Shulman (1986, 1987) has referred to as pedagogical content knowledge (PCK). If teachers lack PCK, 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). However, acquiring agri-food system PCK 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 could emphasize the integration of ethical and scientific content related to agricultural biotechnology. If prospective teachers do not understand how humans use science and technology to design the crops they value, how will their students gain such understandings?

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