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PROSPECTIVE ELEMENTARY TEACHER UNDERSTANDINGS OF PEST-RELATED SCIENCE AND AGRICULTURAL EDUCATION BENCHMARKS

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Abstract

The purpose of this qualitative study was to determine the understandings of pest-related concepts by prospective elementary teachers. Guided by theoretical frameworks for science education and studies on agricultural literacy, a research protocol that included grounded theory and cognitive anthropology was used to surface respondents' understandings of three educational benchmarks for the concept of human management of crop growth. 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. Out-of-school experiences were the strongest determinant of prospective teacher ability to engage in discourse that was compatible with experts. Informants held incomplete understanding of pest-related benchmarks as often indicated in their lack of ability to make connections between scientific, societal, and technological concepts. Informants lacked language to accurately articulate an understanding of the pest-related benchmarks. Most informants lacked understanding of the positive and negative impacts of pesticide use. The identification of agriculture as one of the eight basic technology areas for study by the American Association for the Advancement of Science underscores the need for cooperation between agricultural and science educators.

Introduction

Public debate about science and technology arises out of concern for social issues that entail unknown risks to health, safety, and the environment. The public, however, cannot make valid decisions and take action without an understanding of the principles and risks of modern technological systems. Several factors influence the ability of today's society to acquire the understanding necessary to make valid decisions about complex societal issues.

Modernization—based on the promise of techno-economic progress—has led to the growth of mechanisms to control and contain risks in the adoption of new technologies (Beck, 1992). Yet the general public often has little understanding of the complex interrelationships of technology that constitute conditions of risk in today's world. Hennen (1995) has argued "the shape of the future is increasingly dependent on decisions which are made now, without being able to grasp their consequences in their entirety" (p. 93). These "unknowns" leave many people with concerns for the future and a feeling of distrust for technology and its promise of progress and prosperity. Also, as society becomes increasingly dependent on technology, people abdicate direct control to professionals who understand the concepts involved in its use. Consumers' actions are mediated through technological systems that, because of their complexity, are filtered through experts. If these systems have no or few ill effects, people develop confidence in these networks of technologies and the professionals who operate them. If, however, the systems are confronted with problems of their own creation, e.g., pesticide residues in food, bacterial contamination in meat, "mad cow" disease, etc., society's trust erodes. Hennen (1995) suggested "to the extent that expert systems overreach themselves in handling the consequences of their creations—as a result of their increasing complexity—lay people are forced to expand their outlook" (p. 95).

Society's outlook, however, is often based on a contemporary moral philosophy that only works in a vacuum. Winner (1995) suggested that "the vacuum is created, in large part, by an absence of widely shared understandings, reasons, and perspectives that might guide societies as they confront the powers offered by new machines, techniques, and large-scale technological systems" (p. 65). For example, in the agri-food system, technologies such as pesticides (Sachs, Blair & Richter, 1987; van Ravenswaay, 1995) and genetically modified organisms (GMOs) (Progressive Farmer, 1999) are emerging as global concerns. In the United States, as in Europe before it, a growing number of consumers are skeptical of the benefits promised by these technologies (Hillyer, 1999). Most consumers, however, understand little about the trade-offs that come with the technologies, let alone consider the moral implications of their use.

To assess the trade-offs of technologies such as pesticides and GMOs, individuals need a basic understanding of scientific and technological principles. Acquiring such understanding is a cumulative process that begins when people are very young. Agricultural educators believe that schools must integrate agri-food system concepts into the curriculum to promote understanding of basic principles (Frick, Kahler, & Miller, 1991; Leising & Igo, 1998). Many science educators also believe that agri-food system information and concepts are essential school topics. For example, in 1989 the American Association for the Advancement of Science (AAAS) identified agriculture as one of the eight basic technology areas required for study by U.S. students (AAAS, 1989). Four years later, AAAS defined its K-12 benchmarks for agri-food systems literacy (AAAS, 1993).

There are, however, problems associated with educating the public about the agri-food system. Researchers know little about what individuals understand about this complex system. The Council for Agricultural Science and Technology (CAST) underscores the need for research focused on public understanding of technology. CAST has suggested, "research is needed to develop valid and reliable theories about public perceptions of agrichemicals and other agricultural technologies" (van Ravenswaay, 1995). Decisions about complex societal and environmental issues, such as trade-offs with the use of pesticides or GMOs, require theories to explain how people learn about these interrelationships. With these theories, educational programs can be designed that are compatible with current scientific knowledge.

This study's theoretical framework is undergirded by Piaget's work in cognitive psychology and constructivist theory. Piaget (1952) viewed the human mind as a dynamic set of cognitive structures (schema) that help people make sense of the world around them. Schemas serve as interchangeable slots or placeholders that represent general knowledge structures (Anderson, Spiro, & Anderson, 1978). 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 (Posner, Strike & Gertzog, 1982; 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 agricultural pests and the technologies used to control them.

Frick, Birkenholz, Gardner, and Machtmes (1995) have argued that prospective teachers require assistance to help elementary students develop agri-food system literacy. Others have suggested that such assistance should come in the form of developing teachers' agricultural knowledge and developing their capacity to teach this content (Humphrey, Stewart & Linhardt, 1994; Terry, Herring & Larke, 1992). No research currently exists that examines preservice teachers' understanding of the content they will be expected to teach children about pests, crop protection, and the impact of using pesticides on crops.

Purpose/Objectives

The purpose of this qualitative study was to determine the understandings of eight prospective elementary teachers about national agri-food system education benchmarks from agricultural and science education. More specifically, this study sought understandings of elementary education benchmarks related to pests, crop protection, and the impacts of using pesticides on crops. The objectives of this study were: (1) to determine informants' backgrounds and experiences, (2) to compare prospective elementary teacher understandings with expert understandings for pest-related educational benchmarks for the K-5 grade levels, and (3) to ascertain if commonalties existed among informants with regard to their backgrounds and experiences as well as their understandings.

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 ascertain understandings on the level of individual cognition, non-conventional methodologies are called for. Gardner (1991) has argued 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 of understandings" (p. 145).

To gain firm evidence of understanding, the researcher employed a protocol for inquiry that combined grounded theory (Creswell, 1998; Strauss & Corbin, 1990) and cognitive anthropology (Hamilton, 1994; Frake 1980) to identify cognitive structures and states of cognitive development so as to propose theory about what prospective teachers understand about pest related benchmarks. This methodology —although new to agricultural education research—has been used by science education researchers for nearly two decades (Novack & Gowin, 1984; 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. Prospective teacher selection was based on educational background. Students were sought who had little science background, 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 research interviews in previous scholarship, the researcher developed a synthesis of pest-related elementary level educational benchmarks from the disciplines of science (American Association of the Advancement of Science, 1993) and agricultural education (Leising & Igo, 1998). The benchmarks the participants were questioned about are what experts in science and agricultural education suggest that 5^{th} grade students (those who this group of informants were learning to teach) should understand about pests and the technologies used to control them. Members from Michigan State University's (MSU) Science Education and Agricultural and Extension Education departments reviewed interview prompts and the research protocol. The interviews began with questions about the background of each participant. To link the conversation in a familiar context, interviewees were provided a cheeseburger from a nationally known fast food chain. The researchers hoped that by using this common food, informants could easily express their ideas about the steps this familiar product goes through on its way from production to consumption. Questions required reflection on the cheeseburger's lettuce, because it was easy to link this food component to pest-related benchmarks.

Clinical interviews (Posner & Gertzog, 1982) were used to surface informant understandings of pest-related benchmarks. In each 45-minute interview, approximately five minutes were spent determining demographic background; the remaindering time was spent probing student understanding of benchmarks. These videotaped and transcribed interviews served as the primary data sources. Secondary data consisted of field notes and interviewee products.

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 answer research objectives pertaining to agri-food system understandings. A bimodal coding scheme was used to represent student thinking about the benchmarks. The sophistication of thinking 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 researcher developed expert propositions related to three benchmarks and associated subconcepts. The Science Education and AEE faculty reviewed the propositions for accuracy. Anderson (1995) suggested clinical interviews should be limited in terms of the organization of academic knowledge and the language needed for discourse about the academic knowledge. With this in mind, expert propositions and goal conceptions for elementary content were based on synthesis of science and agricultural education benchmarks (Trexler, 1999). Table 1 lists the key concept, benchmarks, and language needed for benchmark discourse.

Table 1
Key concept, benchmarks, and language

Key Concepts	Benchmark	Language
How do humans manage crops?	(1) Describe how crops may be lost to pests.	pest, damage, loss
	(2) Explain how crops are protected from weeds and pests.	kill, poisons, chemicals, pesticides, poisons, barrier
	(3) Describe the positive and negative impacts of using poisons (pesticides) to protect crops.	poisons, harmful, benefits, profit, positive, negative, labor, resistance, disease, increase, decrease

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 (West, Fensham, & Garrard, 1985). 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 three times. This "persistent observation" (the interview itself and the repeated viewing of the tapes) helped the researcher verify the trustworthiness and credibility of interpretations (Lincoln & Guba, 1986). To ensure confirmability—a parallel to the conventional criterion of objectivity (Guba & Lincoln, 1986)—another researcher evaluated the tapes and concept maps and agreed with the primary researcher on 97% of the subconcept classifications.

Phase three focused on coding prospective teacher responses. The sophistication of thinking about a given benchmark--as represented in the conceptual proposition map—was judged by comparison with expert propositions along two dimensions: quality (compatibility) and depth (elaboration of response). Informants' understandings were coded based on this scheme (Table 2).

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.

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 subconcepts might influence other benchmarks. Patterns within the data were then ascertained by comparisons among individuals.

Findings/Discussion

Research Objective 1: Informants' Backgrounds and Experiences

Table 3 provides information on the prospective teachers' backgrounds.

Table 3
Background of prospective teacher informants

Name	Gender	Ethnicity	School Background	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- Teacher Father- Landscape architect
Molli	Female	European American	Catholic School MSU- El Ed, Special Education	Detroit	Mother- Pre-school teacher Father- 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

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 MSU and majored in elementary education, but some had different minors. Place of origin was not a selection criteria, however, three students came from rural backgrounds, three from the suburbs, and two from the city of Detroit. Occupations of their parents varied.

Table 4
Food and agriculturally related experiences of prospective teachers

Name	Shopping	Cooking	Gardening	Farming
Sid	Yes , mother	Sometimes cooks	Yes	No

Table Continues

Table 4 Continued

Name	Shopping	Cooking	Gardening	Farming
Kat	Yes, mother	Doesn't cook	Yes, with father when young	No
Molli	Yes, mother	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, anything quick	Yes	A little with friends
Guy	Yes, mother	Cooks every night	No	No
Meri	Yes, mother	Loves to cook	Yes	No

As children, all informants shopped with their mothers for food. Their experience with cooking ranged from never cooking to an impassioned love of cooking. For the most part, prospective teachers occasionally cooked for themselves. As for gardening, five informants grew food with their parents, one young woman's grandparents had a garden, and two had no experience whatsoever. Interestingly, two informants had worked on farms.

Research Objective 2: Prospective teacher understandings of pest-related benchmarks.

The second research objective focused on prospective elementary teacher understanding of benchmarks related to (1) crop loss due to pests, (2) crop protection, and (3) the impacts of using poisons to protect crops. In this section, the subconcepts necessary to understand benchmarks are displayed along with prospective teacher compatibility with expert conceptions.

Benchmark 1. Describe how crops may be lost to pests.

Table 5 illustrates prospective teacher understandings of crop loss from pests. It is important to note that an informant needed to understand all subconcepts in order to receive a *Compatible Elaborate* coding (CE)—the goal conception.

Table 5
Prospective teacher understanding of crop loss due to pests

Subconcepts	Sid	Kat	Molli	Kara	Di	Dan	Guy	Meri
(1) Weeds	•				•	•		
(a) competition for space								
(b) competition for sunlight								
(c) competition for minerals and water					•			

Table Continues

Table 5 Continued

Subconcepts	Sid	Kat	Molli	Kara	Di	Dan	Guy	Meri
(2) Animals (insects and other)	•	•	•	•	•	•		•
(a) eating/nesting- growing crops	•	•	•	•	•	•	•	•
(b) eating /nesting- after harvest								
Coding	CS	CS	CS	CS	CS	CS	CS	CS

•- indicates informant understanding of subconcepts
Codings: ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy;
CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate.

Table 5 shows 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 pests, such as rodents and deer. Guy spoke only of losses due to insects. Di, Dan, and Kara specifically stated how these losses might take place: eating of plants while growing or the nesting of insects in the crop. No informant spoke of crop loss after harvest.

Only Sid, Di, and Dan spoke of weeds having a negative effect on crop growth. 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.

No informant spoke of competition for space and sunlight between weeds and crops.

Benchmark 2. How are crops protected from weeds and pests?

As indicated in Table 6, all informants were *Compatible Sketchy* in their understandings related to crop protection. In the expert conception for this benchmark, three methods were listed to protect crops: (a) establishing barriers to animals, (b) killing of pests with pesticides (poisons), and (c) breaking the life cycle of pests through management techniques. No informant spoke of all three methods.

Table 6
Prospective teacher understanding of crop protection

Subconcepts	Sid	Kat	Molli	Kara	Di	Dan	Guy	Meri
(a) Barriers						•		•
(b) Killing with pesticides	•	•	•	•		•	•	•
(c) Breaking life cycles - management					•			
Coding	CS	CS	CS	CS	CS	CS	CS	CS

•- indicates informant understanding of subconcepts
Codings: ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy;
CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate

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 firsthand 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, did you say insecticides 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? 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. 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 of 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 em. 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, we had beans, and 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- You talked about rabbits a while ago and protecting it [lettuce] from rabbits. Is there anything else they would need to . . .
S- 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- 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.

Benchmark C. Positive and negative impacts of using pesticides to protect crops.

As shown in Table 7, all informants held a *Compatible Sketchy* understanding of the positive and negative effects of pesticides to protect crops. This benchmark is very complex and entails multiple subconcepts. The expert proposition included both benefits and liabilities. Benefits included: (a) reduction in labor, (b) increase in crop yield, and (c) decrease in human disease. On the other hand, liabilities included: (a) expense of pesticides to farmers and ultimately to consumers, (b) pest resistance to poisons, (c) contamination to the environment, and with it, death and morbidity to living things, and (d) decrease in the use of sustainable practices based on pesticide reliance.

Table 7
Prospective teacher understanding of the positive and negative effects of pesticides

Subconcepts	Sid	Kat	Molli	Kara	Di	Dan	Guy	Meri
Positive								
(a) reduced labor for farmers				•		•		•
(b) increased yield/profit for farmers	•	•	•	•	•	•	•	•
(c) less disease – better human health					•			
Negative								
(a) expense of pesticides for farmers					•			
(b) pest resistance								
(c) environmental contamination	•	•	•	•		•	•	•
(d) lack of sustainable practices								
Coding	CS	CS	CS	CS	CS	CS	CS	CS

•- indicates informant understanding of subconcepts
Codings: ø--No evidence; N--Nonexistent; IE--Incompatible Elaborate; IS--Incompatible Sketchy;
CI--Compatible/Incompatible; CS--Compatible Sketchy; CE--Compatible Elaborate

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, but only two had a deeper understanding of how these technologies might benefit humans. Di stated that pesticides could reduce human disease, while Kara, Dan and Meri spoke of decreasing labor costs through their use.

Informants' discourses were extensive relative to negative impacts of pesticides as compared 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 discussed death and morbidity in other animals, but did not specifically mention human beings. Only Di spoke of the expense of pesticides for food producers. She also mentioned that people were fearful of pesticides, and that this fear 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 that 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- Why would that be important?
K- So that the farmer's crops weren't destroyed by a plague of locusts.
I- 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- How about more broadly speaking?
K- We won't have any lettuce for our Big Macs®.
I- You talked about insects and insecticides. Can you think of—what are the positive things?
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 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 were the driving force, not health.

I- OK, how about anything that would be a trade-off, a negative, a liability of using….
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 it's 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 Big Mac®], but they want to sell it to people and they will sell it any way 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 inorganic, human-made ones.

Research Objective 3: Commonalties with regard to informant backgrounds and experiences and their understandings of pest-related benchmarks.

The study's third objective assessed commonalties among informants with regard to background and experiences and their understanding of pest-related benchmarks. The goal was to determine if associations between these variables were apparent. These variables included demographic background and food and agriculturally related experiences.

Deeper levels of benchmark understanding appeared to be linked with experiences held by informants. For example, Kara, whose father was a farmer, described both positive and negative impacts of pesticides in detail. On the other end of the spectrum, Molli, who was from Detroit and had never gardened, was the most suspicious of pesticide use and questioned the motivations of those who used them. Interestingly, the two informants who mentioned the production of organically grown crops spoke of their or a friend's conviction toward environmental activism.

Conclusions/Recommendations

Informants in this study appear to be typical of most prospective elementary teachers, although some grew up in rural areas, which is probably unlike most entering the education field. This rural perspective appeared to be linked to a deeper understanding about pests, pest control, and an appreciation of both the positive and negative effects of pesticides. Those informants who did not have such background were less likely to hold extended discourse about these topics. Apparently, out-of-school agricultural and rural experiences were the strongest factors in the development of schema that promoted discourse most compatible with agri-food system experts. If these prospective teachers are to teach this subject matter, they would benefit from educational experiences that scaffold their understandings of these topics.

For the most part, prospective teachers' conceptions of pests were limited to insects and rodents that ate crops in the field. These informants did not have adequate schema to discuss crop loss after harvest from pests, nor did the majority mention losses due to weeds. In addition, they appeared to lack understanding of the competitive nature of weed pests. This is noteworthy because (Trexler, 2000) found that 5th grade students also did not discuss weeds as crop pests. Considering this, it may be important to insure that teacher education include this concept. This is of particular import because of pesticide fear and because the most controversial GMOs, e.g., Round-Up Ready™ crops, are designed to tolerate herbicides. But based on this research, most prospective teachers are not aware of the impact that weeds have on crops; therefore, they hold an incomplete schema from which to make informed decisions.

Generally speaking, informants' understandings of crop protection were limited to pesticides. They had little understanding of alternative measures for controlling pests. With their apparent fear of pesticides and limited knowledge of management techniques, it appears that these prospective teachers could benefit from exposure to alternative means of crop protection. Such exposure could come in science courses as they learn about competition within ecosystems. To bring relevance to these concepts, managed ecosystems such as farms could be used as examples.

An understanding of the positive and negative effects of pesticides appears to be primarily limited to increased crop yield and environmental harm from the improper use of these technologies. Prospective teachers with background and experiences in rural areas were more likely to understand why farmers used pesticides. The vast majority of this study's participants did not grasp the concept that pesticides can prevent post-harvest crop loss as well as preventing human disease caused by eating pest-damaged food. In addition, informants dwelled on acute, low probability risks of catastrophic environmental damage while ignoring issues of gradual pest resistance and shifts away from sustainable practice as a result of pest-control technologies. This conclusion is supported by Kunreuther and Slovic's (1978) findings that people are not inclined to worry about low probability hazards and have difficulty conceptualizing risk over a long time horizon. Ideally, with the current concern for a "greener" environment, these college students would have been exposed to alternative agricultural practices in science or social studies courses, but their answers did not reflect this exposure. If they were exposed to these concepts, they had not internalized them. It is apparent, though, that for these prospective teachers to teach elementary students about these vary concepts, they require additional background knowledge and experiences to scaffold their limited understandings.

Finally, further research can shed light on pest-related understandings of prospective elementary teachers. Specifically, additional use of this study's research protocol by other researchers, with similar but different groups, can lead to transferability of findings. These studies might target areas where "sketchy" (incomplete) conceptions are present.

Implications

Clinical interviews were fruitful in surfacing informant understandings of pest-related benchmarks; therefore, this methodology has implications for researchers as they seek to ascertain what people "understand" (Frick, Kahler, & Miller, 1991; Frick & Wilson, 1996) about the agri-food system. Survey methodologies dominant in agricultural education research cannot readily ferret out idiosyncratic cognitive structures. More broadly speaking, university science and agricultural educators may find this study of interest, as it underscores the need for cooperation between these disciplines. This is of particular concern in terms of prospective teacher understandings of competition within managed ecosystems, which is what the majority of the Earth's surface is quickly becoming. Finally, this study has implications for teacher educators because prospective teachers did not possess content knowledge or understandings necessary to teach elementary curricula specified by both science and agricultural educators.

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