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A QUALITATIVE STUDY OF URBAN AND SUBURBAN ELEMENTARY STUDENT 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 science by elementary students (N = 9). Guided by theoretical frameworks for science education and studies on agricultural literacy, clinical interviews were used to surface fifth graders thinking about three benchmarks for the concept of human management of crop growth. Data analysis included validating benchmarks and language to guide the discourse, generating conceptual proposition maps, coding student responses for comparison with expert propositions, and confirming or disconfirming patterns among students. Out-of-school experiences were the strongest determinant of student ability to engage in discourse that was compatible with experts. Students held incomplete understanding of pest-related benchmarks as 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, especially urban, nongardening students lacked an understanding of pests and their control in the growth of plants for food. Core biological concepts, e. g. plant growth needs, may provide a structure for integrating agri-food system principles into the elementary school curriculum.

Introduction

Science and technology are increasingly called upon to aid society in the name of progress, prosperity, and economic growth. As technological innovations are adopted, however, society becomes more fearful of their risks. Beck (1992) has suggested that industrialized societies are transitioning to "risk" societies where "the gain in power from techno-economic progress is increasingly overshadowed by the production of risks" (p. 13). Philosophers of science Rouse (1987) and Feenburg (1995) have cautioned that society should critically question the use of science and technology to determine what it values.

In the agri-food system few technologies are more feared than pesticides. Sachs, Blair, and Richter (1987) found that consumers were increasingly concerned with the risks of pesticides to the environment and to personal health. Interestingly, perceptions of risks from residues of agrichemicals in food differ greatly among members of the public. van Ravenswaay (1995) found that "approximately one-fourth [of respondents] perceives a great chance of harm from pesticide residues in food whereas approximately the same percentage perceives very little or no chance" (p. 1). Like pesticides, the use of genetically modified organisms (GMOs) to reduce crop loss is emerging as a global concern (Progressive Farmer, 1999). In the United States, as in Europe before it, a growing number of consumers are skeptical of the benefits promised by this new technology (Hillyer, 1999).

To assess the trade-offs of pesticides and GMOs in terms of human health and safety and the environment, individuals need to possess a basic understanding of scientific and technological principles. Acquiring such understanding is a cumulative process that begins when people are very young. If U.S. society is to have discourse about risks and benefits of agricultural technologies, schools must integrate agri-food system concepts and examples into curricula to promote literacy (Leising & Zilbert, 1994; Trexler, 1998). Science educators also believe that agri-food system information and concepts are essential for public school curricula. In 1989, the American Association for the Advancement of Science (AAAS) in its visionary work "Project 2061: Science for All Americans" identified agriculture as one of the eight basic technology areas for study by U.S. students.

Problems arise in regard to educating the public about the agri-food system; researchers know little about what individuals understand about this complex system. The Council of Agricultural Science and Technology underscores the need for research focused on technology. The Council suggested that "more research is needed to develop valid and reliable theories, methods, and conclusions 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 and GMOs--require theories to explain how people come to learn about complex interrelationships. With these theories, educational programs and curricula can be designed to help learners construct schema that are compatible with current scientific understandings.

This study's theoretical framework is built upon research from science education. To determine the accuracy of idiosyncratic understandings, science education researchers have compared student conceptions with those of experts (Driver, Guesne, & Tiberghien, 1985; Posner, Strike, & Gertzog, 1982). These studies, based on Piaget's work in cognitive psychology, tend to follow the theory that learning occurs through the construction of mental schema. Schema serve as interchangeable slots or placeholders that represent general knowledge structures (Anderson, Spiro, & Anderson, 1978).

Currently there exists a growing body of knowledge on the "agricultural literacy" of students, prospective teachers, and adults (Birkenholz, Frick, Gardner, & Machtmes, 1994; Flood & Elliot, 1993; Frick, Birkenholz, Gardner, & Machtmes, 1995). In agricultural education, abundant knowledge and positive perceptions gleaned through survey research are often equated with literacy. Frick and Wilson (1996) suggested, however, that agricultural literacy involves, not simply a cache of facts, but "a basic understanding of agriculture" (p. 59). Presently, agricultural educators do not clearly understand what elementary students "understand' about the agri-food system.

Purpose/Objectives

The purpose of this qualitative study was to determine elementary student understandings of agri-food system educational benchmarks. More specifically, this study sought student understandings of 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 elementary student understandings with expert understandings for pest-related educational benchmarks.
3. To ascertain if commonalties exist among informants with regard to their backgrounds and experiences, and to their understandings ofpest-related benchmarks.

Methodology

Population

The population for this study included nine purposefully selected 5th grade students. Fifth grade students were selected as informants because they: a) have reasonably well-developed language skills, b) are typically still classified as elementary students, and c) fall into a grade that is defined within the agri-food system benchmarks. Their selection was based upon type of school attended (private, public, charter, middle, elementary), gender, socioeconomic status (SES), geographic location of residence, and ethnicity. A $6.00 honorarium was provided for participation in the study.

Data Collection

Clinical interviews were used to surface informant understandings of pest-related benchmarks and to identify cognitive structures and states of cognitive development (Novack & Gowin, 1984; Posner & Gertzog, 1982). Each interview took roughly 45 minutes. Approximately 5 minutes were spent determining demographic background; the remainder probed student understanding of benchmarks. Interviews were videotaped and transcribed, serving as the primary data sources. Field notes and products created by the interviewees were consulted as secondary data.

Interview Questions and Protocol

To ground the research interviews in previous scholarship, I developed a synthesis of pest-related educational benchmarks from the disciplines of science (American Association for the Advancement of Science, 1994) and agricultural education (Leising & Zilbert, 1994). Members of Michigan State University's (MSU's) Departments of Science Education and Agricultural and Extension Education (AEE) reviewed questions and protocol. The interviews began with questions about the background of each student. To link the conversation in a familiar context, interviewees were provided a cheeseburger from a nationally known fast food chain. I hoped that by starting from this common basis informants could easily express their ideas about the steps this familiar food goes through on its way from production to consumption.

Interviewees were asked to separate the cheeseburger into its component parts so that the complex food could be more easily analyzed. Questions required interviewees to reflect on the lettuce; this food was selected because it was the least processed of the cheeseburger's components. Further questions probed participant understandings of three pest-related benchmarks.

Analysis of Data

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) strategy for representing highly complex student thinking to answer research objectives pertaining to agri-food system understandings. At the onset I must call attention to my biases because I am the lens through which the analysis of this qualitative data was made. Personally, I believe that all people require some level of agri-food system understanding so that they can participate in decisions relative to how the earth's resources are used. In analyzing the "talk" of the elementary children, I tried to bracket my bias and listen to only the students' words and the meaning they were trying to convey. However, even with this bracketing, my bias, my own reflexivity, most likely influenced my interpretation of data and the conclusions and recommendations drawn from the study.

Analysis of data involved four phases. First, I developed expert propositions related to three benchmarks. These propositions were validated by MSU's Science Education and AAE faculty. Anderson (1995) has suggested clinical interviews be organized around academic knowledge and language needed for discourse about specific benchmarks. With this in mind, expert propositions and goal conceptions for 5th grade students were based on synthesis of science and agricultural education benchmarks (Trexler, 1997a). Table 1 lists the key concept, benchmarks, and language needed to engage in discourse about the benchmark. Much of the language used-e.g. poisons, comes directly from "Benchmarks for Science Literacy" (AAAS, 1993).

Table 1. Key Concepts, Benchmarks, and Language

Key concept	Benchmark	Language
How do humans manage crops to promote growth?	Describe how crops may be lost to pests.	pest, damage, loss
	Explain how crops are protected from weeds and pests.	kill, crop protection, chemicals, pesticides, poisons, barrier
	Describe the positive and negative impacts of using poisons (pesticides) to protect crops.	poisons, harmful, benefits, costs, 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 student thinking for each benchmark (West, Fensham, and Garrard, 1985). Finally, I verified maps for accuracy by comparing them repeatedly to interview tapes of informants. At a minimum, each tape was viewed three times. This *persistent observation* (Lincoln & Guba, 1986) added to the credibility of findings, which is parallel to internal validity in more traditional positivistic inquiry.

In phase three, I focused on coding student responses. The sophistication of student thinking about a given benchmark--as represented in the conceptual proposition map--was judged along two dimensions: quality (compatibility) and depth (elaboration of response) by comparison with expert propositions. Student understandings were assigned codes based upon this comparison scheme (Table 2).

I sought confirming and disconfirming evidence of patterns among individuals in the phase of analysis (Miles and Huberman, 1994). This was accomplished by two procedures. First, each benchmark was analyzed across individuals. And second, holistic portraits of student thinking were analyzed to ascertain how understanding or misunderstanding of subconcepts might influence understanding of another benchmark.

Findings/Discussion

Research Objective 1: Informants' backgrounds and experiences.

A. Background

Table 3 shows data relative to informant background including gender, race, school, and geographic location of where they were raised, parental occupation. There were nine elementary students in this study: five were female and four were male. They were of European or African ancestry and came from urban and suburban locations. Four student informants attended parochial school; the remainder were in public schools. The parental occupations ran the gamut from janitor to pharmacist. Informants were divided by Socio-Economic-Status groups: lower, lower middle, and upper middle classes.

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.

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

B . Experience

Table 4 summarizes experiences of elementary students. All elementary students had shopped with their mothers for food. Most had helped out in the kitchen, but they did not play a major role in food preparation. Only one elementary student had had a cooking class in school. Relative to gardening, three students had never been involved in growing food. No elementary student informant had ever worked on a farm, but one had lived in areas near farms.

Research Objective 2: Student understandings of pest-related benchmarks

The second research objective focused on

Table 3. Elementary Student Background Data

Name	Gender	Race	School	Raised	Parents' Occupation	Socio economic Status
Jay	Male	African American	Public School	Lansing	Father- Janitor Mother - State civil servant	Lower middle class
Jill	Female	European American	Catholic School	Lansing	Father- State civil servant	Lower middle class
Tom	Male	European American	Public School	Idaho, Oregon, and Lansing	Father- Science teacher	Lower middle class
Jim	Male	African American	Lutheran School	Detroit	Mother- Word processor	Lower class
Mona	Female	African American	Lutheran School	Detroit	Father- Airport porter Mother - Pre-school teacher	Lower class
Sara	Female	African American	Public and Lutheran School	Detroit	Stepfather- Machinery repair Mother- Shipping clerk	Lower class
Tim	Male	European American	Public School	Suburb of Lansing	Father- Mental health administrator Mother- Secretary	Upper middle class
Ema	Female	European American	Public School	Suburb of Lansing	Father- Pharmacist Mother- Pre-school teacher	Upper middle class
Liz	Female	European American	Public School	Suburb of Lansing	Father- Engine designer Mother- Teachers' aide	Upper middle class

elementary student understanding of the benchmarks related to a) crop loss due to pests, b) crop protection, and c) the impacts of using poisons to protect crops. Codings of elementary student understandings for the benchmarks are found in Table 5. Detailed descriptions of the findings follow.

Benchmark A, Describe how crops may be lost to nests. In Benchmark A "Describe how crops may be lost to pests" informants were coded into three classifications: Compatible Elaborate, Compatible Sketchy, and Nonexistent (Table 5). Only Ema was Compatible Elaborate in her description of the two parts to this benchmark

Table 4. Food and Agriculturally Related Experiences.

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

Table 5. Elementary Student Understanding of Pest-Related Benchmarks

Benchmarks	Jay	Jill	Tom	Jim	Mona	Sara	Tim	Ema	Liz
A. Describe how crops may be lost to pests.	CS	CS	CS	CS	N	N	CS	CE	CS
B. Explain how crops are protected from weeds and pests.	CS	CS	CS	CS	*N*	*N*	*CS*	*CS*	*CS*
C. Describe the positive and negative impacts of using poisons to protect crops.	N	N	CS	CS	N	N	N	CS	CS

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

--weeds and animal pests. Jay, Jill, Tom, Jim, and Tim were Compatible Sketchy; and Mona and Sara were Nonexistent. Ema, Liz, and Tim said crops needed to be protected from weeds. Tim explained in detail about how dandelions "stole" water from trees, while Liz's response to why weeds were removed from her home garden was based only on them being "tacky." She lacked an understanding of how crops are lost to pests. Liz described her home garden (L = Liz and I = Interviewer):

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

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

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

I- What would be wrong if they grew bigger?

L- The garden would look really tacky.

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

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

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

Relative to animals as pests to human crops, only Ema and Liz stated that these pests could be wild animals, rodents, and insects. Jay, Jill, and Tim spoke only of rodents, and Tom and Jim only of insects, Additionally, Tom, Jim, Ema, and Liz knew that these animals could affect crops by eating and nesting in them, while Jay, Jill, and Tim only mentioned animals eating plants--this may be logical as they viewed animals affecting plants as large. Interestingly, no informant mentioned birds as pests to crops. In addition, neither Mona nor Sara spoke of pests at any time during the interview.

<u>Benchmark B. How are crops protected from weeds and nests?</u> All informants--with the exception of Mona and Sara--were coded Compatible Sketchy. Mona and Sara did not mention pests in Benchmark A. Therefore, they did not have the requisite background to understand that crops needed to be protected from pests--they were coded Nonexistent. In the expert conception for this benchmark, three methods were listed to protect crops: a) establishing barriers to pests, b) killing pests with poisons (pesticides), and c) breaking pest life cycles through management techniques. No informant spoke of all three methods, but one--Tim--added the use of scarecrows and decoy snakes, which seemed plausible.

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

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

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

E- Urn, bugs . . . .

I- Tell me about that.

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

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

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

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

E- Yeah, they could urn spray the lettuce.

I- With what?

E- With like bug spray or something.

I- What does that do?

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

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

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

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

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

L- I don't know, both?

I- Both?

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

No informant mentioned the use of management techniques such as crop rotation or diversified cropping systems as a means to control pests.

Benchmark C. Positive and negative impact of using poisons to protect crop. The expert conception for Benchmark C was very complex and described the positive and negative impacts of using poisons (pesticides) to protect crops. The positive impacts stated were the: a) reduction of time and labor, b) increase in crop yield and its resultant decrease in the price of food, and c) decrease in human disease caused by pests. Conversely, negative impacts included the: a) expense of purchasing and using pesticides, b) contamination of the environment resulting in morbidity and mortality to living things, c) resistance to pesticides by pests and resulting in dependence on products that no longer serve their purpose, and d) the move away from sustainable practices because of a reliance on "quick fixes" such as pesticides. No informant included more than one positive or negative impact of pesticides. In fact the majority (Jay, Jill, Mona, Sara, and Tim) were coded Nonexistent for this benchmark. The remaining Compatible Sketchy informants (Tom, Jim, Ema, and Liz) all stated that sprays would help plants by preventing their destruction, thereby leading to an increased yield. Thomas also mentioned that this would increase profits for the farmer. On the negative side, Tom, Jim, and Liz mentioned that sprays could result in contamination of foods. Liz explained that people might be allergic and plants might not tolerate the material:

I- So if you sprayed this stuff, you said like OFF™ right?

L- Ya [overlapping speech].

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

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

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

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

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

I- Anything that's a disadvantage to that?

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

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

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

I- So do you always wash off your fruit?

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

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

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.

Croups of informants displayed marked differences related to their understanding of the benchmarks. The European American, upper middle class SES group members were the only informants to describe weeds as pests that farmers might need to protect crops against. Two informants from this group--Tim and Ema--explained that the weeds would compete for growth requirements--specifically light and water--with other, more desirable plants. Ema explained that crops are lost to weeds because they competed with crops for space and for growth requirements.

I- You talked about plants growing and blocking out something.

E- Yeah, there might be other weeds or plants or something that are growing too close and the leaves might block out the sunlight from the lettuce and make it die, because it doesn't get much sunlight.

I- So what would the person who is growing the lettuce do?

E- Probably chop down the weeds or before they grow the plants, if it's like has another vegetable a little farther.

Conversely, urban Detroit informants who had never gardened had no schema related to pests. They did not express any understanding of a) how pests (insects or weeds) affect crops, b) how crops might be protected from pests, or c) the impacts of using pesticides.

Conclusions

The findings of this study suggest that 1) experiences play a pivotal role in elementary students' understanding of pests, 2) students lack well develop schema and language to discuss pests and their control, and 3) core biological concepts undergrid pest related understandings. Listed below are a more detailed account of these conclusions.

Out-of-school experiences were the strongest determinant of an informant's ability to engage in discourse that was compatible with experts. This is supported by the fact that informants who held understandings most compatible with expert conceptions, time and again, related their discourse to personal experiences and not school-based learning. It is particularly noteworthy that urban, non-gardening students appeared to lack a schema for pest-related benchmarks. One might speculate that this resulted from their lack of experiences with growing food and from a dearth of opportunities to travel and gain a broader perspective. In other words, elementary student experiences appeared to be the strongest shaper of their schemata relative to the educaitonal benchmarks.

Informants were most commonly coded "Compatible Sketchy" for their agreement with experts. This indicates that they held incomplete understandings of science and agricultural education benchmarks. These incomplete understandings were often found in concepts that required informants to make connections between scientific, societal, and technological concepts. Most students lacked knowledge and understanding of pests and their control. Without this schema, (which agricultural and science educators suggest be held at this age) there is weak or incomplete scaffolding on which to build understandings necessary to intelligently weigh the positive and negative effects of using pesticides and other crop technologies, e. g., GMOs. Related to this was informants' lack of language to accurately articulate an understanding of benchmarks. This is noteworthy because Fine (1990) suggests that humans, as social beings, use "language as the primary shaper of meaning" (p. 129), and because Cazden (1988) has argued that speech unites the cognitive and social" (p. 1). Without language, then, there can be no conveyance of meaning.

Elementary students were unable to convey an understanding of basic agricultural production. This is similar to Thomson's (1996) finding that adult food consumers lacked language to express their thoughts about the agri-food system. This dearth of language appears to be related to school-based core biological concepts (plant and animal growth needs, competition between organisms, etc.) that undergird other more complex concepts which scaffold an understanding of pest-related benchmarks. Without this initial structure, students cannot build a foundation for learning.

Recommendations

Two recommendations are offered based on the findings of this study. First, further research can shed light on pest-related understandings of elementary students. Specifically, additional use of this study's research protocol by other researchers with similar, but different groups, can lead to generalizability of findings. These studies might target areas where "sketchy" (incomplete) conceptions are present. Second, it appears that gardening programs for urban students could help them gain experiences that may be absent. As gardening is instituted as an experiential component of learning, students can be exposed to core biological concepts (listed in the implication section), thereby helping them to understand interrelationships between crops and plants and animals.

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. Dewey (1933) has argued that to "understand" is a personal affair, one that entails an individual's struggle to grasp meaning. The survey methodology that currently dominates the agricultural education discipline cannot readily ferret out idiosyncratic cognitive structures.

Students held little knowledge of weeds, and the majority did not understand that weeds compete with crops for sun, soil nutrients, space, and water. This underscores the need for curriculum designers to include these topics in curricula. It is of particular import that members of society understand these concepts as they weigh the costs and benefits of pesticide use. This is increasingly important because herbicides are the most widely used pesticides in the United States (McEwen & Stephenson, 1979; Spindler, 1983) and because of the growing debate over herbicide-resistant GMO crops (Hillyer, 1999).

Agricultural and science educators need to further examine the standards and benchmarks written for the agri-food system. Some educator may believe that the complexity of the schema and language necessary for elementary students to articulate a compatible and elaborate understanding of this study's pest related benchmarks may be beyond what can be expected of these students. What is need, then, is for experts to more fully fleshed out conceptual maps of subconcepts necessary for an understanding of complex interrelationships found in the agri-food system.

Societies of experts--such as university agricultural and science educators--may find this study of interest as it underscores the need for cooperation between them. Specifically, developmental ideas are missing or are seldom linked in the curricular frameworks of both disciplines. This was apparent as I developed a synthesis for each discipline's pest-related benchmarks. These ideas are foundational to developing a sequenced understanding that builds on less complex subcomponents. Pesticide use serves as an illustrative example. To understand why humans use this technology one must understand that: a) humans are animals that compete for food with other animals, e.g., insects, rodents, etc.; b) animals have growth requirements (food, water, shelter, air, space); c) these growth requirements are in limited supply, d) humans select certain plants and animals to grow for food; e) animals and plants that humans grow can be food for competitors; f) humans, to control animals and plants that destroy their food, employ technologies that kill them, limit their number, or prevent them from reaching the crop they choose to grow; and g) humans must weigh trade-off of the use of technologies--such as pesticides--in regard to health and safety, and the environment.

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