Chapter 7
Rural Science Education: Water and Waste Issues

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Making the Case

Science education, to be effective, must respond to the special needs of rural communities, schools, teachers, and students. This focus is upon appropriate science for rural communities using the same definitions, research base, and rationale that can be made for any other setting.

Among the major problems of schooling in rural settings are: (a) the feeling of isolation, (b) too few students within a school to permit specialization and appropriate foci for all interests and needs, and (c) fewer teachers to provide a breadth of expertise and experiences for students to draw upon. Many of these problems are being ameliorated by funds to deliver better and continuing in-service, computer linkages, and distance learning capabilities exemplified by fiber-optics networks which allow two-way visual and audio communication.

Science education is in continuing crisis as it is redefined in ways that are more appropriate for all. It is becoming more and more apparent that a single science curriculum does not serve all people well. Even though Americans take pride in local control of the nearly 16,000 independent school districts in the United States, what is taught continues to be determined by curricular materials made available nationally. Usually these mainline textbooks in a given curriculum enjoy 85% of the market (Harms, 1977). Further, when textbooks are analyzed, there is less than a 10% variation in the content. This similarity does not serve rural schools well.

Project 2061 (Rutherford & Ahlgren, 1989) has established a reform agenda in science education for the 90s with its publication *Science for All Americans*. This statement was also adopted by the huge Scope, Sequence, and Coordination (SS&C) Project of the National Science Teachers Association. With nearly $30 million now involved in 2061 and SS&C, the direction for current reforms is established. Further, these projects are affecting the emerging national *Standards* (National Committee on Science Education Standards and Assessment, 1992, 1993a, 1993b, 1994a, 1994b) which clearly define science in broader terms. Science content is now defined with eight facets, including:

1. Science as Inquiry.
2. Physical Science.
3. Life Science.
4. Earth and Space Science.
5. Science and Technology.
6. Science in Personal and Social Perspectives.
7. History and Nature of Science.
8. Unifying Concepts and Processes.

These efforts elaborate on the NSF-sponsored Project Synthesis which issued a report more than a decade ago. Project Synthesis was conceived utilizing four goal clusters (actually justifications) for school science. These four were:

1. Science for Meeting Personal Needs. Science Education should prepare individuals to use science for improving their own lives and for coping with an increasingly technological world.
2. Science for Resolving Current Societal Issues. Science education should produce informed citizens prepared to deal responsibly with science-related societal issues.

3. Science for Assisting with Career Choices. Science education should give all students an awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests.
4. Science for Preparing for Further Study. Science education should allow students who are likely to pursue science academically as well as professionally to acquire the academic knowledge appropriate for their needs (Harms 1977).

The National *Standards* seem to exemplify how the first three goal areas must also define teaching, professional development, assessment, content, and program sequence. In the past, science has been defined by specific discipline-bound concepts and generalized (and glamorized/generic) process skills used by practicing scientists.

Of course, concept and process skills remain basic to science programs. However, they do not provide the structure, a direct line to curriculum planning, and/or the only aspects used in assessing student learning. For the 90s, the power and centrality of context is emerging as the most important consideration. How are students engaged with their own minds? Do they think, analyze, debate, or identify with the things that characterize the science curriculum? In typical situations students do not; they merely perform as they are asked to do without any thought as to why or how it can be used outside the classroom or laboratory.

Perrone (1994) has recently discussed how student engagement can be attained. His eight points provide another view of the needed content and theoretical foundations for science teaching. Perrone's summary of experience and research indicate the ways students can be/are engaged for real learning:

1. Students help define the content.
2. Students have time to wonder and to find a particular direction that interests them.
3. Topics have a "strange" quality—something common seen in a new way, evoking a "lingering question.
4. Teachers permit—even encourage—different forms of expression and respect students' views.
5. Teachers are passionate about their work. The richest activities are those "invented" by teachers and their students.
6. Students create original and public products; they gain some form of "expertness."
7. Students *do* something—e.g., participate in a political action, write a letter to the editor, work with the homeless.
8. Students sense that the results of their work are not predetermined or fully predictable.

Rural students are more isolated than their urban counterparts. However, they are also closer to nature and to many problems associated with the natural world and human plundering of the environment. Rural students often do not have access to as many scientists, engineers, researchers, or industrial professionals as students in large urban centers. Of course, modern communication technology is beginning to reduce this problem. However, there is a continuing need for more support to provide the needed communication via modern technologies. There is richness in rural students learning from other students in non-rural environs. Where numbers are a problem, sharing of data collected—and data from wide geographical areas—can add to the significance of technological devices—and a reduction of the isolation that occurs in the rural settings. Experts from around the world can be used as sources of information. Surely information from computer retrieval systems has never been easier to access. But the hardware, software, and expertise needed to utilize such advances remain a problem for many teachers and schools.

The last decade has resulted in much new information concerning how all humans learn. Interestingly, the decision was made in 1983 to conduct definitive research into how learning occurred as needed information to reform U.S. science and mathematics education and to help resolve the perceived economic crises that was putting the U.S.A. into jeopardy in worldwide trade and general economic competitiveness. Our national problems were seen as related to the quality of science education in the nation's schools.

The emerging research (Mestre and Lochhead, 1990; Resnick 1986, 1987) seems conclusive that instead of finding how our best students learned science (undergraduate science and engineering majors) it was found that these most successful and motivated students had not learned. Instead they were merely committing definitions and explanations to memory and repeating them when asked in class or on examinations. Skills taught in the laboratory were the same. Students could follow directions and demonstrate mastery. However, they could only repeat the skill. The best students could not transfer the concepts or processes to use in new situations.

These discussions led more cognitive scientists to new questions of learning and eventually to research reports dating back to Vico (1858) nearly 300 years ago. A new interest and respect for Constructivism as a theory of learning has emerged. Most professional societies now advance constructivism as a learning model and have defined new teaching strategies that promote such learning.

Basic to the theory is the belief that all humans construct their own meaning from their own explanations of things they see, do, or ponder. The Association for Supervision and Curriculum Development has led this movement with articles in *Educational Leadership* and special publications like *The Case for Constructivist Classrooms* (Brooks & Brooks, 1993). Constructivist teaching practices consist of:

- Encouraging and accepting student autonomy, initiation, and leadership.
- Allowing student thinking to drive lessons; shifting content and instructional strategy based on student responses.
- Asking students to elaborate on their responses.
- Allowing wait time after asking questions.
- Encouraging students to interact with each other and with the teacher.
- Asking thoughtful, open-ended questions.
- Encouraging students to reflect on experiences and predict future outcomes.
- Asking students to articulate their theories about concepts before presenting teacher understanding of the concepts.
- Looking for students' alternative concepts and designing lessons to address any misconceptions (Yager, 1991, p. 56).

Constructivist practice involves students to a greater degree in terms of identifying questions, offering personal explanations, and devising tests for the validity of such hypotheses generated by students. These actions have all been used to define science. For example, Simpson (1963) has offered a single precise definition of science:

> Science is an exploration of the material universe in order to seek orderly explanations (generalizable knowledge) of the objects and events encountered: *but these explanations must be testable* (p. 82).

Such a view of science exemplifies constructivist teaching practice and learning that can become a part of each student's thinking/learning framework.

In so many ways small rural communities (with the smaller class sizes that are often found and the ties to farms and farming communities) are ready-made for trying constructivist teaching. With a means of communicating with persons around the globe (modern technologies, including the computer), students in rural settings are in prime position for better opportunities for real learning. Indeed, rural science education may provide answers for some of the complex problems which are found in urban settings.

In Iowa, efforts have been underway since 1983 when the Chautauqua Program was initiated with major NSF support and sponsored by the National Science Teachers Association. Although only funded nationally for three years, the Iowa Chautauqua Program has flourished in Iowa, serving over 2,500 teacher since its inception. The model has now been validated and accepted as an exemplary in-service model by the National Diffusion Network (NDN). The model consists of the following features:

1. A two-week leadership conference for 25 of the most successful teachers from previous years who want to become a part of the instructional team for future workshops.
2. A three-week summer workshop at each new site for 30 new teachers electing to try Constructivist practices and strategies; the workshop provides experience with such practices where the teachers are the students. Time is provided to plan a five-day constructivist unit to be used with students in the fall.
3. Use of a five-day STS unit in the classrooms of all summer participants during September or early October.

4. A three day fall short course for 30-50 teachers (including the 30 enrolled during the summer); the focus is upon developing a month long module where constructivist practices are used along with an extensive assessment plan.
5. An interim communication with central staff, lead teachers, and fellow participants, including a newsletter, special memoranda, monthly telephone contacts, and school/classroom visits.
6. A three day spring short course for the same 30-50 teachers who participated in the fall; this session focuses upon reports by participants on their experiences with constructivist teaching and the results of the assessment program.

Arising from the Iowa Chautauqua are several examples from rural schools that exemplify the reforms discussed above. With the "flood of 1993" dominating life in Iowa for a whole year, it is not an accident that this real world issue provided a focus for science study that readily exemplified the new goals for science education, including those characterizing the National *Standards*.

An Integrated Model With a Rural Focus

Given the special needs and circumstances in which students and teachers in rural settings find themselves, how can science programs be designed to personally engage students? What does a science program look like when the criteria for excellence discussed in the first part of this chapter are considered? How do rural programs differ from those created with students in urban and suburban settings. We argue that the notions which are personal, relevant, and local apply in all settings. The differences lie in the issues and problems that students are trying to resolve and the local cultural dimensions. This type of thinking challenges long held beliefs about curriculum design, not to mention our thinking on teaching, learning, and assessment (Hurd, 1991). The typical science program offers very few opportunities for making connections to the real world.

Interconnections between science disciplines are limitless and seem to merge when they are set in a real-world context. Disciplines are transcended and become embedded naturally within the connections as they are uncovered in the natural world. The following model (see Figure 1) serves as the conceptual foundation for the examples from practice that are included in this chapter. This model is centered upon the idea of using a kaleidoscope—each time the scope is rotated, new connections are formed, creating a different pattern—always the same pieces reconnecting to form a new whole. The pattern possibilities are endless.

Personal experiences are the forces that move the model, driving the instructional processes. Learning becomes a "knowledge-based" event, linked to the here and now. Knowledge is explored in a real-life context. The content is not considered to be intrinsically important; in fact, it is determined by the issues and student interest rather than predetermined guidelines. The process results in many "personal" and "cultural stories" (Drake, et al., 1992).

The following teacher stories capture how this model can be put into action in rural settings. The Iowa Scope, Sequence, and Coordination Project (SS&C) encourages teachers to develop stories about their practices as part of the curriculum transformation process. Teachers are asked to create eight of these stories each year—two per quarter. They add an important contextual dimension to what otherwise would simply be a traditional outline of major concepts and a listing of activities. The context we feel is the key for making science experiences personal and relevant. These stories have become the centerpieces for creating curriculum materials that go beyond the status quo and serve to stimulate an exchange of ideas among teachers in Iowa. Sharing of the stories occurs on a regular basis within the local school districts, at SS&C statewide meetings, and across the fiber optics network. Teachers come to see themselves as master learners involved in analyzing and reflecting on their teaching practices, always concerned with improving. These personal teaching stories serve as powerful change forces (Fullan, 1993).

The Model in Action: What a Tragedy! A Middle School Example

Iowa and much of the midwest suffered through what climatologists and meteorologists termed a "one hundred year flood." The flood of 1993 has left scientists, as well as students in Curt Jeffryes middle school

Rural Model: Integrated Curriculum

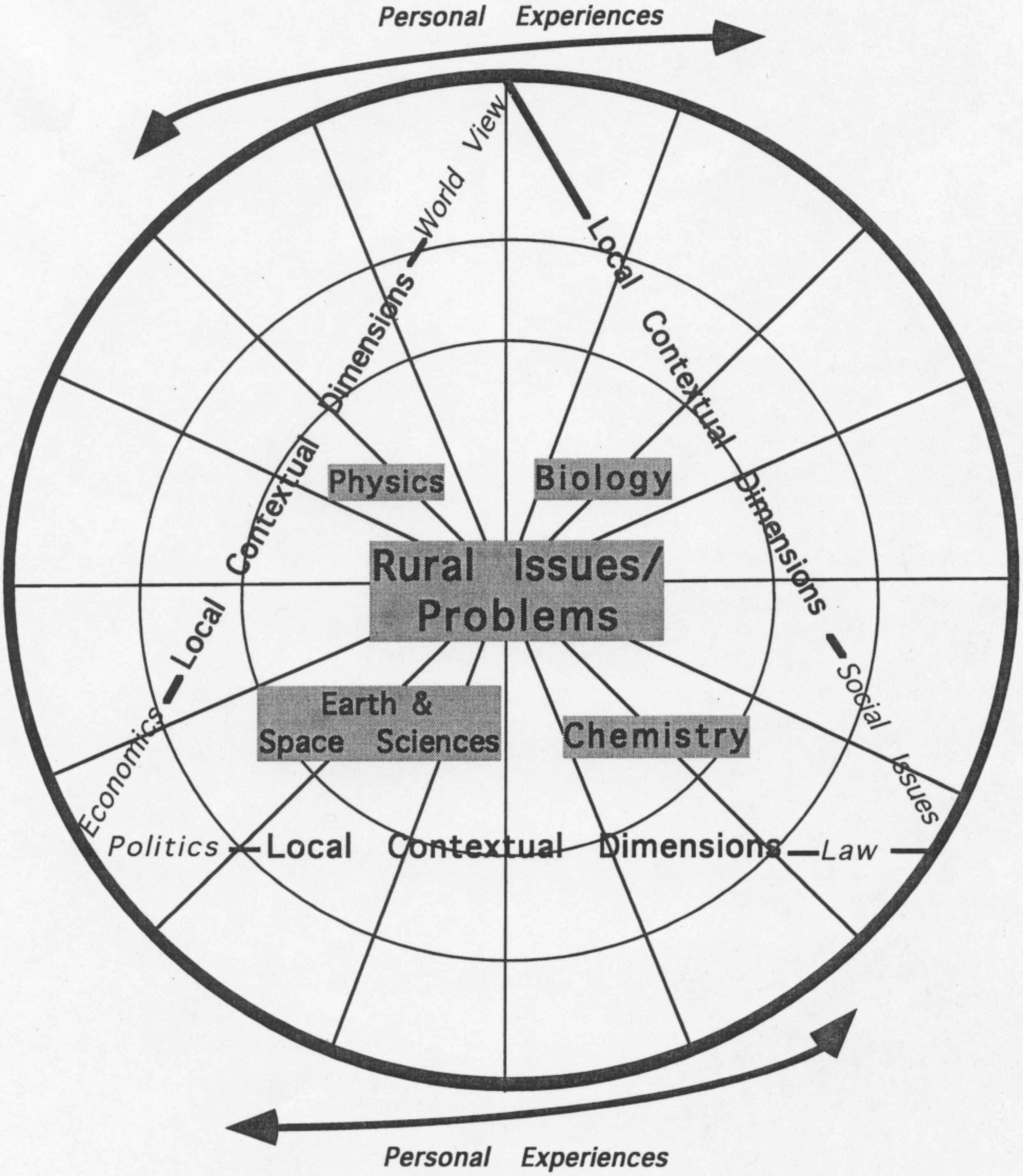


Figure 1. *Model*

classes, with questions that relate to all science disciplines. Scientists have hypothesized the long-term effects and short-term effects of the flood and several new theories have emerged. Students at Burton R. Jones Middle School in Creston, Iowa, took a look at the flood of 1993 and were challenged to examine some of the flooding problems in their local area.

The Teacher's Perspective: Curt Jeffryes's Story

On the first day of school I started classes with a simple question. "What was the most significant event that happened in Iowa this past summer?" Without fail the students replied, "the flooding." Then I asked, "How did the flood effect Creston?" This was a more difficult question because Creston has no major river running through it and the fact that Creston is the highest point of elevation between the Mississippi River and Missouri River in the southern part of the state. The questions began to flow.

Wade said, "I have a question. I live by the creek and it didn't flood, but our basement filled with water several different times and ruined lots of stuff. Was that an effect of the flood?" Other students asked: Why were some areas affected and others not? Did anyone really escape the flood of '93? Could the devastation suffered during the flood have been prevented or minimized? Does mankind have the ability to control natural events like floods? What caused the flood and will it come again? Could we have prevented or controlled the flood? In each class student questions about the flood began to form. These questions would become the basis for the investigations of the flood of '93 and also a basis for the active inquiry that we would be doing during the first semester.

I could clearly see how the water cycle, the topography of Iowa, historical perspective of past floods and prevention of flooding resulting from these floods, and environmental questions of soil erosion, water quality, and land use could be explored. I began to map the unit in my mind and to anticipate the directions our study might take. This mapping is something that I do with all my students. The following mind web (see Figure 2) was created by putting our ideas together at the beginning of this experience.

The challenge was to keep the web growing as we moved through the student investigations in the module. The mind web becomes the centerpiece for monitoring interdisciplinary connections. Through class discussion and teacher mediation, each class decided on the directions of inquires for the module. My curriculum is made up of a series of these modules, usually eight in the series. There were whole class projects and small group inquiries as part of this module.

During the inquiries, the students had to seek out a number of resource people within the community who could provide various forms of data and answer specific questions in relation to the flood. Beau, whose father works at the water treatment plant, provided us with detailed information and models which explained the changes that occurred with the source water during the flood and how it is cleaned and purified. Another student talked to the wastewater treatment plant manager and found information on how the flood affected its operation and also how wastewater is cleaned. Another student contacted a local college biologist who was doing a similar companion study in his microbiology classes and learned about the changes that seemed to be occurring in the source water and its ramifications for people. One group of students contacted a soil scientist at the local ASCS office and engineers at a local firm in relation to looking at how to read topography maps and building flood control structures. Another group of students and teachers planned an interdisciplinary field study to look at flood damage in one of our county parks and at the success of how earlier conservation work had been affected by the flood. Student inquiries were assessed using a pre/mid/post scheme.

Putting our ideas into action became the concern when the student inquires were completed and the results shared with the class and community. The students decided to continue a soil erosion project that had been started several years ago at a county park. They also decided to repair any damage structures at the park as a result of the flood. They were particularly interested to see if the check dams of the past had survived and if they had done their job of preventing soil erosion. They shared with their parents the knowledge of soils and building location in Creston and the potential risks that accompany building in areas like this. Several donated their time to work through church organizations in flood cleanup projects in Des Moines.

It would be difficult to predict how I would change or modify this unit of study for another year. The great flood of '93 was by all accounts an event that might not occur for another 100 or more years. The story, however, has not ended. The effects of the flood continue to unravel before our eyes and next year maybe something new will emerge for us to investigate.

What an Odor! A High School Example

Clayton, and most counties in Iowa, are facing a new controversy involving livestock production. Issues are being raised statewide that call into question problems with odor, and water pollution caused by animal production. Why isn't there a law to stop the dumping of waste into streams? Can't the odor be controlled? What is the real cause of the odor? Does the DNR have anything to do with regulations? Are more than farmers to blame? Even "rural" America is not immune to issues of pollution and odor. Many technologies seem to be available that would help alleviate the problems. The question then is why aren't they being implemented? Elkader high school students in Bill Crandall's science classes are busy taking a closer look at these questions.

From the Teacher's Perspective: Bill Crandall's Story

Like most teachers preparing for a new term with a new group of students, I was concerned about how to start the semester in a meaningful way. What would capture students' attention and provide a venue for modeling an image of science truer to its nature? I began the year certain that I could excite most of the students with an issue dealing with water quality. I took a group of students to a cold water stream to do some measurements that coincided with an ongoing DNR study. As we traveled to the study site with the windows rolled down, we passed several farm sites that gave off the pungent odor of Iowa's number one livestock commodity, hogs.

The students immediately asked the questions that had been in the news all summer. Dan: "What *does* the feedlot runoff do to the environment?" Ann: "Can't something be done to stop the smell?" Tom: "My relatives in Wright County say there is a guy building chicken and hog confinement places all over the county. They're worried about the smell and water pollution. Should they be?" Jim: "Is anybody trying to figure out how to solve some of these problems?" It became obvious from the outset that this issue would not be easy to keep focused in one area. The students as usual were already verbally exploring several issues related to farm waste management that in and of themselves would make for exciting student investigations.

Students were responsible for keeping track of the questions that arose during their investigations. The following web (see Figure 3) illustrates the connections that they uncovered during the module investigations. The students worked in groups—each group tackling a different aspect of the problem.

Perhaps the greatest challenge we have to overcome being in a small community is the isolation factor and lack of local resources. During the information gathering phase, the students took advantage of the resources at hand and gathered information and data tied to their specific questions. The CD ROM in the school library provided the students with a listing of magazine articles (mostly in *Successful Farming*) dealing with the issue of farm odor. They connected to the Internet and gleaned information and expertise from other states using the Turbo Gopher program which allowed them to build a multimedia database with pertinent e-mail addresses, mailing addresses, and telephone numbers. In the database the group entered the area of interest or expertise of each human resource. The students designed a survey to assess attitudes, and understandings about issues associated with farm waste management. The results were then transferred to a database and graphs of the results were produced. We were beginning to realize the scope of this problem.

The second phase of the inquiry process focused on the actual testing of water for substances coming from waste sources. The group decided to look at the problems with surface run-off carrying waste. One of the students said "I heard that the trout hatchery has to monitor its water because the spring that feeds it drains a large area of farm land." We were shortly in transit to the Big Spring Trout Hatchery northwest of Elkader, Iowa. When we arrived, we were able to interview some of the technicians at the hatchery who explained the history of the hatchery and some of the problems involved in using spring water to hold trout. They also conducted tests on the water from the spring as well as the Turkey River that the spring flows into. We were looking for any evidence of high nitrates in the water. This would mean that some form of fertilizer was escaping into the water which could come from agricul-

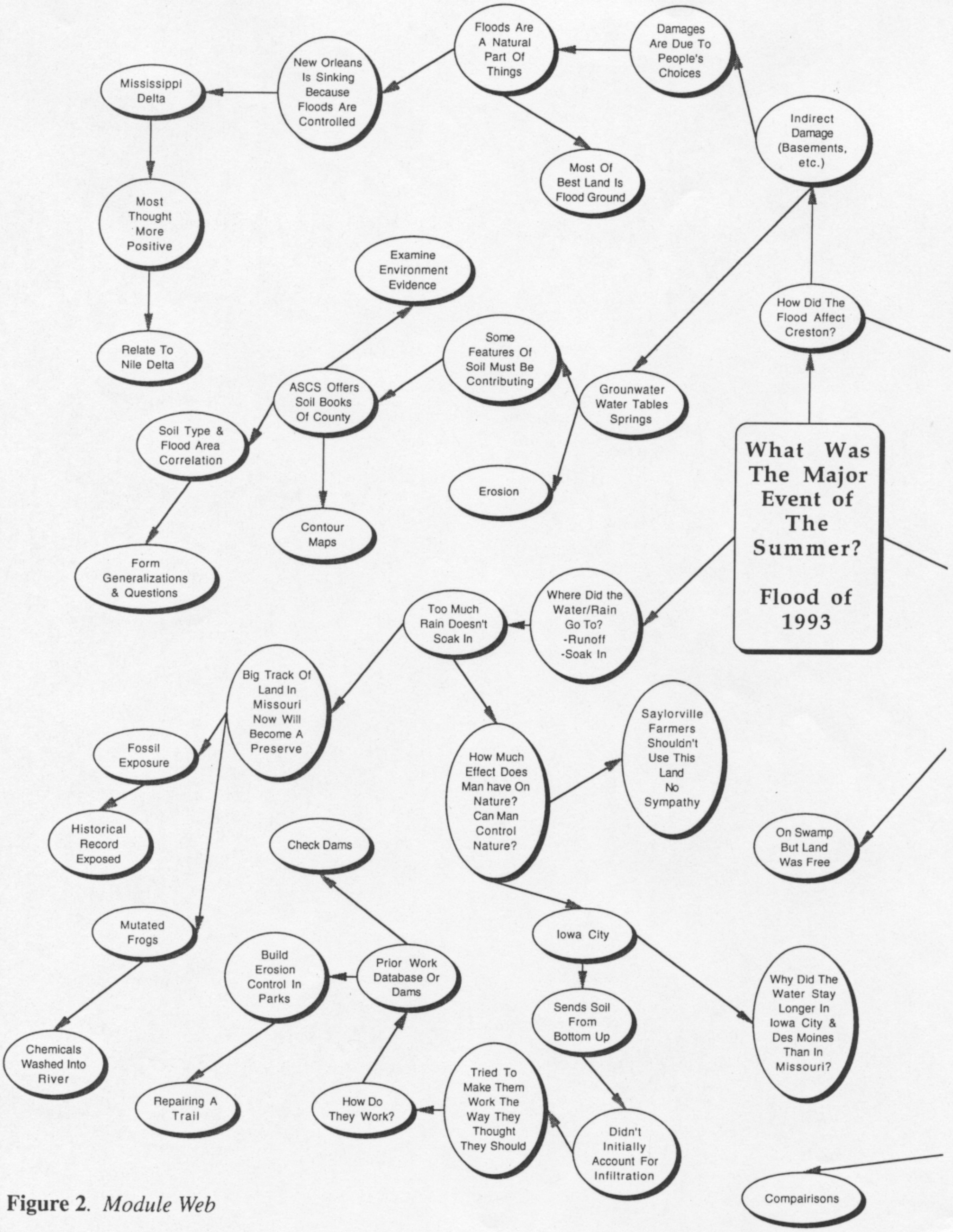
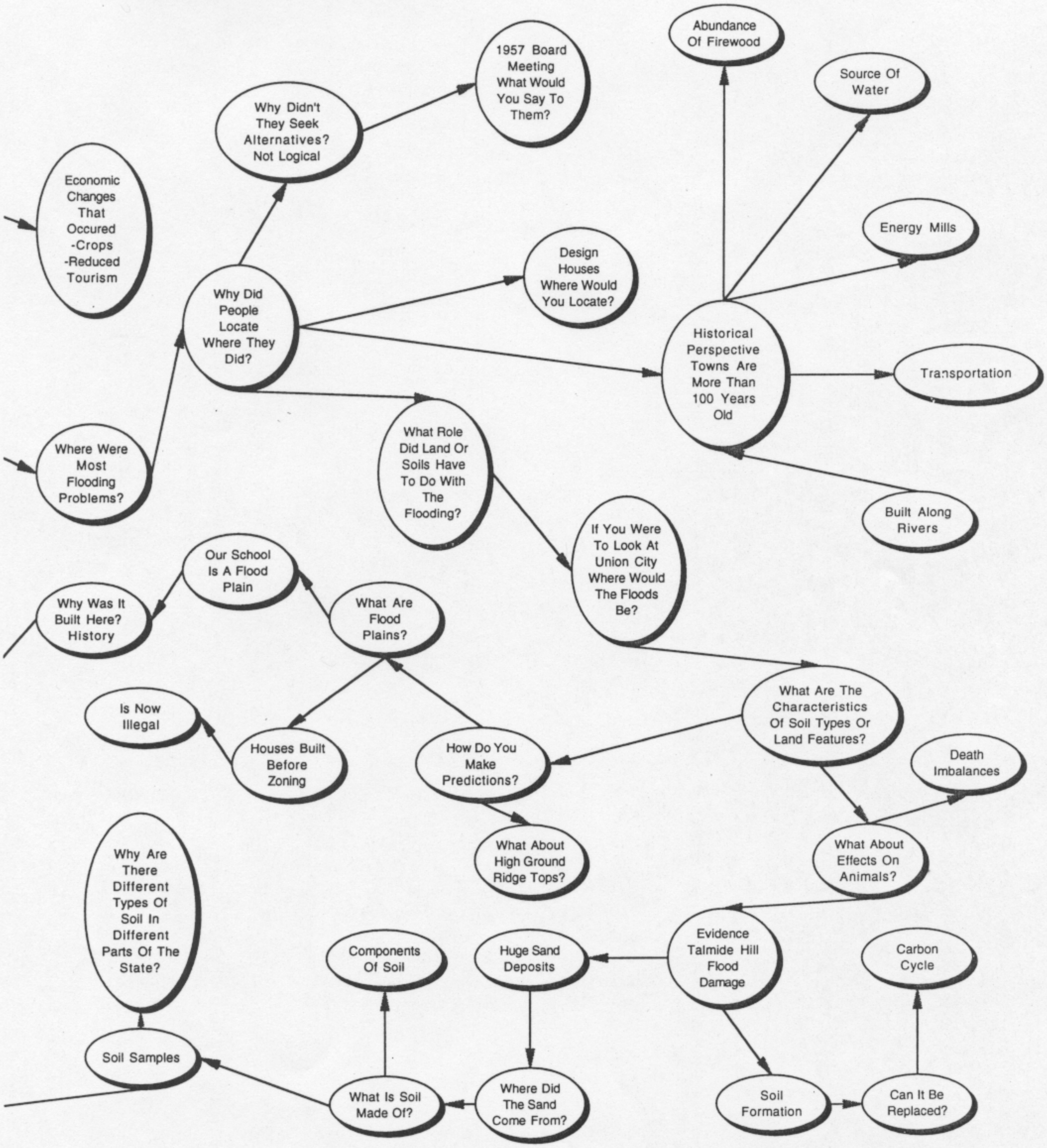


Figure 2. *Module Web*

The Flood '93 Module Web



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QUESTION WEB: FARM ODOR

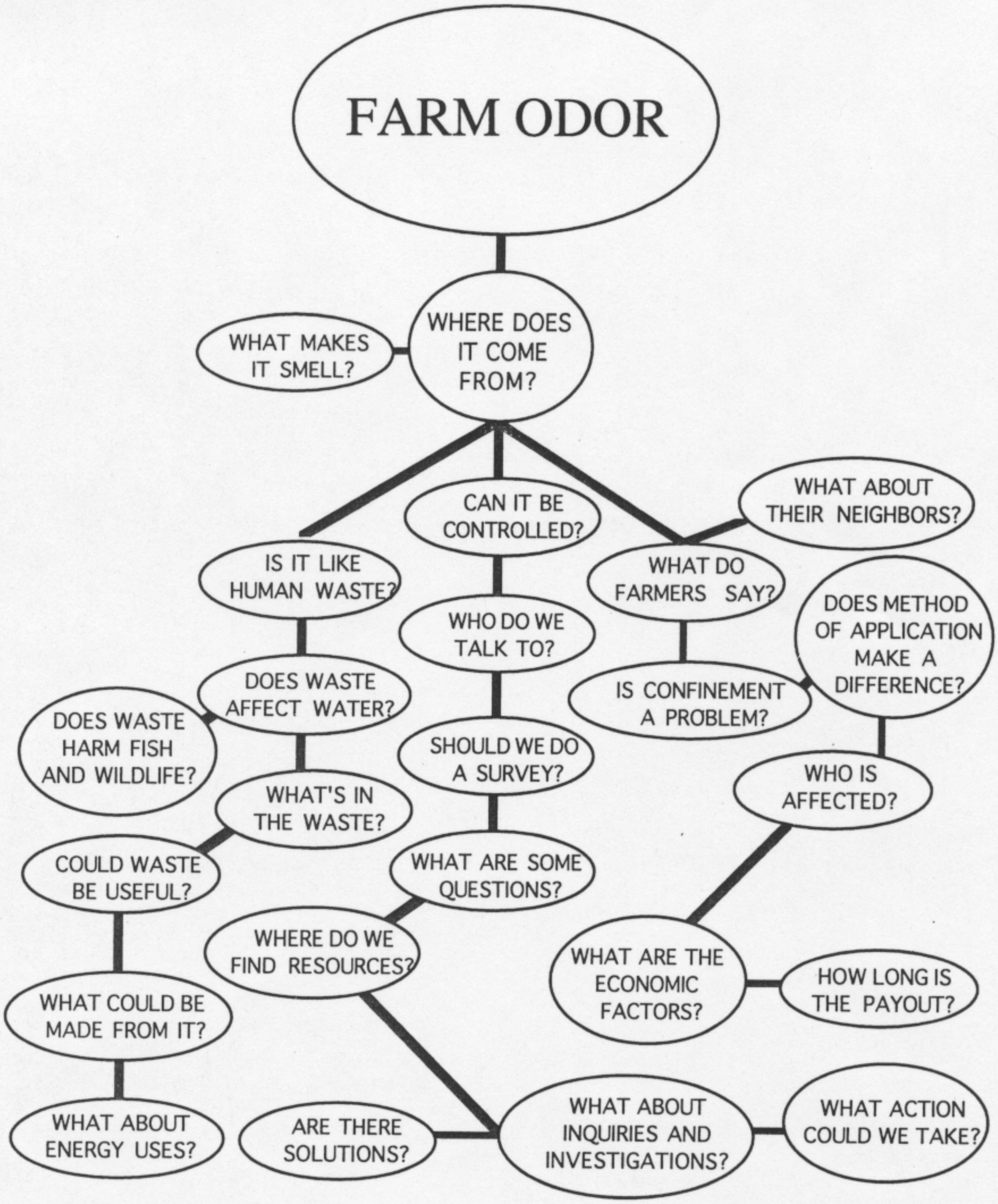

Figure 3. *Question Web*

tural fertilizer or from farm feedlot (manure). A data table was started to help monitor the quality of the water over a long period of time. When our visit to the trout hatchery was complete, the group decided to investigate ways to use the waste in a manner that was environmentally conscious.

The students began to wonder about a film they had seen called "Kilowatts From Cowpies." The film had illustrated how people were producing methane from animal manure at farm sites in Florida and California. One of the students wondered "Why can't we do that in Iowa?" The second strand of our issue had been established. What were the possible alternative energy sources that could be derived from farm waste? Could this manure be used to produce methane? We moved on to explore the possibilities. Students visited a farm to see the process of methane production in action. Tom and Bill took a video camera and set out to interview people about using existing structures to produce methane. In their travels they taped several types of structures commonly used to hold waste. Steel, earthen, and concrete lagoons are all being used, and appear to be able to be retrofitted for capturing methane. Education and economics are key to a change in the way we look at managing this resource.

The issue of farm odor and waste management is complex. What may be a solution in one place won't work in another. Each problem needs to be carefully studied and the most practical methods for abatement applied. Our group strongly feels that the future will see multiple uses for waste as a resource on farms, in cities, and in towns. Our studies have shown that there are many ways for both farmers and municipalities to deal with this issue.

During the final phase of this project, the students moved into action to produce a multimedia presentation of their research findings. The data from the survey graphs were transferred to the Astound computer program which allowed them to add sound and graphics to the graphs. The students made a presentation to the school board when the AV program was done. Copies of the program were made available to the community and were used by the county agricultural extension office.

What a Waste! An Elementary Example

The possibilities of recycling were being discussed in Charles City, IA. Even though many of the municipalities throughout the state had recycling programs, Charles City had yet to act. Some of Iowa' communities were operating under the assumption that recycling was not needed in Iowa. This article raised the serious questions: How can we reduce the amount of waste being taken to the landfill? What types of waste could be recycled, reused? How do you distinguish between different types of plastics? Are we running short on landfill space in Iowa? The sixth grade students at Jefferson Elementary decided to take the problem into their own hands and started looking at the possibilities for making recycling a reality in Charles City.

The Teacher's Perspective: Janet Dunkel's Story

Our recycling module began with a headline in the newspaper: "Charles City to Consider Recycling Options". The students were captured by the idea. I knew this issue was one that could take us in many different directions. I asked the students to bring in items from home that they thought could be recycled. We really collected an amazing assortment. Many plastic items were part of the collection. One student asked: "How can you tell which plastic items can be recycled? What do those markings on the items mean?" These questions led us into a number of inquiries related to density and volume. The students generated questions related to the decomposition of the items brought to school. We decided that our challenge was to uncover the aspects of this issues that were unique to Charles City. We were ready to begin our investigations.

The students worked in small groups which really promoted cooperation among them. The students began to collect information and data related to their questions. The class created a survey that they sent home to their parents. This gave us valuable information on personal viewpoints regarding the issue. The other students in the school were interviewed as well. The data were entered into the computer and analyzed. The students contacted outside resources—plastics engineers, city/county waste management officials, waste management workers, DNR officials, and health officials. The list kept growing. During this phase we explored many key science concepts related to the issue. I found that many of the activities from the textbook or other supplemental curriculum material worked well to illustrate these concepts. I found student interest to be much higher when activities were embedded in a creative context.

A portfolio assessment scheme was used to help the students keep track of their progress. This portfolio housed the results of their lab investigations, a written record of the process, computer disks, graphs, charts, reports, full-group assignments, and written tests and evaluations.

The students decided that there was a definite need for recycling in the Charles City area. They had been bringing milk jugs to school for one of our investigations related to volume. They realized that these jugs were "space hogs" in the landfill—not to mention our classroom. The students wondered how to get a milk jug recycling program going. We knew we needed space to store the jugs, some way to crush them, and someone to haul them to the recycling center in Wisconsin. A school neighbor got us started by providing an empty garage where we could store the jugs; the local grocery store provided a machine to crush and bale the plastics; and a student's parent provided the semi to haul the plastics. We were in business. Soon though the project grew beyond our limits. The Boy Scouts had already come to our rescue lending a helping hand. We decided to take a proposal to the city council. The students were able to convince the council members to take action and today our class can be proud of the fact that Charles City has a multifaceted recycling program that we started.

Final Perspective

Each of these examples provides a glimpse of the integrated model to science instruction in action. Students are engaged in purposeful learning experiences. They have the opportunity to use what they learn to solve real world problems. The teachers have come to realize that the questions the students should be testing are their own. Science teaching becomes a matter of helping students realize that indeed all knowledge is interconnected, available, and useful in dealing with problems. For these reasons, teachers of science in rural settings have great potential for leading in science education reform. Successes of teachers in rural settings have been astounding in the Iowa Chautauqua Program. The revision of the total science program in SS&C school has also been easier and more striking in rural Iowa schools in terms of the effects of their studies in making a difference in the quality of life in the communities as a whole. Perhaps science education in rural settings will provide the most conclusive and useful examples of reform. The examples provided here are indications that this may be true.

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