Unraveling the Scientific, Social, Political, and Economic Dimensions of Environmental Issues Through Role-Playing Simulations

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Introduction and Background

Most college-level science courses fail to provide students with a true appreciation of the nature of science (Nelson et al. 1998). Often very structured and fairly intense, they tend to cover a lot of "material" that instructors consider essential. Such courses typically include laboratory sessions that tend to rely on a series of isolated activities. Consequently, students often come to view science as a body of information or "knowledge" to be memorized, while failing to discover and experience other dimensions of science and scientific inquiry (reviewed in Abd-El-Khalick and Lederman 2000; McComas 1996). A number of national initiatives are focusing on changing the nature of college-level *science* teaching (Shulman 2000). These include interdisciplinary science and environmental education courses for future teachers, which can serve as effective contexts for expanding students' conceptions of science.

One powerful means to create a more authentic environment for students to learn science and expand their conceptions of the nature of science is within simulations, in which students take on specific roles (Aubusson et al. 1997; Pennock and Bardwell 1994). *Role-play simulations* typically occur over an extended time period. They expand more traditional concepts of role-playing and debates by creating a context that is more dynamic and authentic (Webb 2002). Such simulations involve multiple groups of individuals, each with particular focus, which reflect specific backgrounds, histories, and competing agendas. Students take on specific roles within these groups that require significant personal investment as they try to understand the nature, thinking, beliefs, and perspectives of their character (McKeachie 1994; Pennock and Bardwell 1994). These types of role-play simulations can result in dynamic environments that oblige

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participants to critically examine their own perspectives and understandings, as well as those of their peers. Consequently, participants develop more robust understandings of abstract concepts (Webb 2002), such as the political and social nature of science.

This chapter focuses on a role-play simulation within an optional college-level interdisciplinary science course designed for preservice teachers and liberal arts students. The role-play simulation utilized a United States Senate Subcommittee hearing on the use of Bt (*Bacillus thuringiensis*) genes in corn. Bt genes in corn enable the plant to produce an insecticide within its vegetative structures. The curricular design of this simulation was based on the work of Harwood, MaKinster, Cruz, and Gabel (2002), who used a Senate Subcommittee hearing to explore global climate change. However, unlike the Harwood et al. project and some of the more focused simulations within the Project Wild (Council for Environmental Education 2003) and Project Wet curricula (Project WET 2003), the time frame for this simulation extended over a period of 3.5 weeks. This allowed students to explore the material in greater depth, and incorporate numerous teaching strategies and topics of current interest in science education (simulations, role-playing, driving questions, oral presentations, technology integration, portfolios, reflection, and concept mapping).

The goal of this chapter is to present and analyze an experience that enables preservice students not only to expand their conceptions of science and environmental inquiry, but also to understand better how science is applied to real-world environmental issues. This unit can be replicated using other environmental topics and in other types of courses. Senate Subcommittee hearings are appropriate for college or university science courses, secondary science courses, science methods courses, and interdisciplinary science courses. At the end of this chapter, other simulation curricula are discussed that exemplify the potential of this pedagogical strategy in the context of emerging technologies. In addition, there is a discussion that describes how the use of such simulations can broaden our definition of what it means to inquire into an environmental issue in productive and meaningful ways.

Unit Description

The role-play simulation unit utilized a United States Senate Subcommittee hearing on the use of Bt (*Bacillus thuringiensis*) genes in corn. This unit consisted of eight, 85-min class periods and involved several instructional strategies (Table 1). *Bacillus thuringiensis* is spore-forming bacteria that poison many types of insects, primarily butterflies and moths. It became a popular sprayed pesticide because it poisoned fewer non-target species than chemical insecticides; however, like chemical pesticides, precipitation could wash it off from the plants. A major solution to this problem was the development of genetically engineered corn that expressed the Bt gene within the plant tissue itself (Bessin 1999). This recombinant technology

Table 1 Schedule of topics and assignments for Senate Subcommittee hearing

Day	*Topic*	*Assignment*
1	Introduction/Concept map/Overview	Comparative reaction paper
2	General discussion and library research session (*Classroom and library*)	Summary of group position
3	General discussion and group work (*Classroom and library*)	Annotated bibliography
4	Portfolio discussion and PowerPoint presentations (*Computer lab*)	Outline of presentation
5	Feedback on presentation and group work (*Computer lab*)	First draft of PowerPoint presentation
6	Senate hearing – Day 1 – Initial arguments	PowerPoint presentations
7	Senate hearing – Day 2 – Follow-up questions, debate, and discussion	Legislative decision (senators only)
8	Senate Subcommittee Statement and debrief	Portfolios and individual reflections

enabled the plants' tissues to express the Bt toxins that are poisonous to insects. Interestingly, Bt toxins are not poisonous to humans due to differences in the pH levels in our digestive tracts.

Initial Concept Map

Prior to the Senate Subcommittee hearing simulation introduction, students were divided into groups of three and asked to make a concept map with different scientific disciplines as the central concepts. The concept maps were then combined to make a class concept map of "Science" (Fig. 1). This map almost exclusively described each science discipline relative to the sub-disciplines within that area. Several students stated that they focused primarily on how textbooks are organized or on the classes that they had taken in the past. This experience initiated a brief discussion about the nature of science and scientific knowledge. The students' ideas were validated, but the primary issue raised was that the concept map might be limited in scope when one considers the nature of science and how science is applied in the "real world." This conversation eventually led to a brief introduction of the science behind Bt genes in corn and a reading assignment for the next class.

Introducing the Unit

To begin exploring and discussing some of the issues surrounding Bt genes in corn, students read two papers, *Transgenic Pollen Harms Monarch Larvae* (Losey et al. 1999) and *False Reports And The Ears Of Men* (Shelton and Roush 1999). The first paper stated a number of concerns regarding the use of Bt Corn and its potential

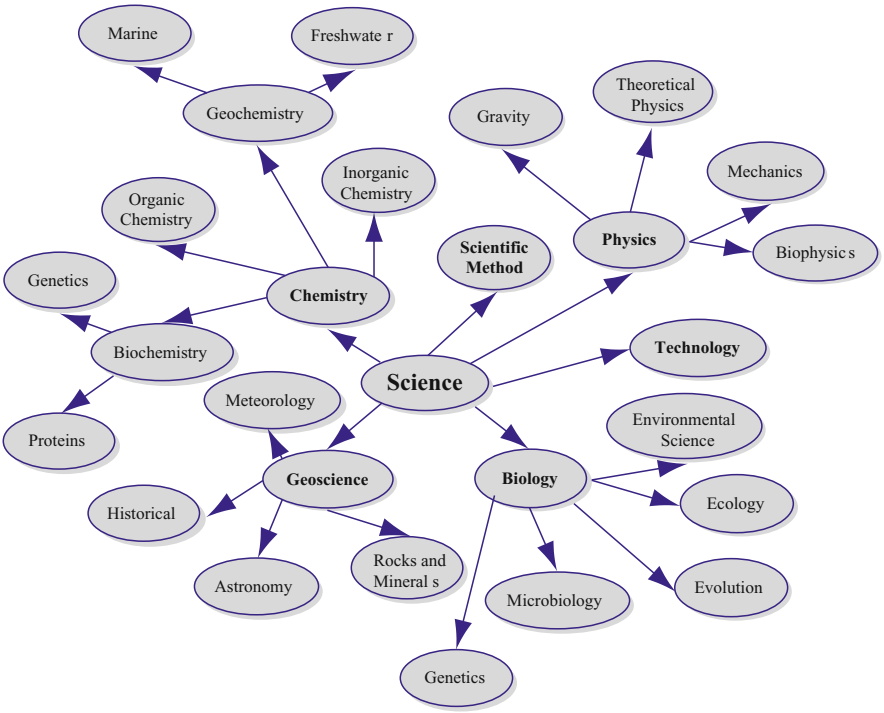

Fig. 1 Initial concept map constructed around the topic of "Science"

impact on monarch butterflies eating vegetation along the edges of Bt Corn fields. The authors argued that a significant number of monarchs were being killed by Bt toxins that were carried to vegetation at the edges of the field by airborne corn spores. The second paper attempted to refute these claims. The students were engaged in a lively discussion about the two papers, but no clear consensus was reached. In fact, most of the students said they were unsure about whether or not Bt Corn was of significant concern.

The course instructor used this opportunity to introduce the Senate Subcommittee hearing simulation by describing the instructional tasks to be undertaken over the next several weeks. He described what the Senate hearing would entail, and presented the driving questions for the hearing. The following questions guided both the student group investigations and the Senate Subcommittee hearing:

1. Are there or are there not legitimate concerns regarding the use of Bt genes in corn?
2. What are the options to manage the use of Bt Corn?
3. What additional research or legislation might be useful in addressing the first two questions?

Three students were assigned the role of senators and the rest ($n = 16$) were divided into six special interest groups:

1. NY State Farm Bureau
2. Food and Agriculture Organization of the UN
3. Monsanto Company
4. Genetic Research Scientists
5. Greenpeace
6. Environmental Defense Organization

The special interest groups included local, international, corporate, scientific, environmental, and legal groups that have an actual interest in the issues surrounding genetically modified food. For the next class, each student group wrote a description of their group, the issues of concern for their group, and what it is that they do. The senators had to adopt a political party and affiliate themselves with a particular state. This provided the senators with a particular mindset in terms of a specific political party and set of constituents whose interests they were to represent during the hearing.

Preparing for the Hearing

In preparation for the Senate Subcommittee hearing, the special interest groups had four primary responsibilities. First, they had to solidify their positions on Bt Corn; second, groups conducted a thorough literature search for relevant information and research; third, they developed a PowerPoint presentation to use during the hearing to present their case; and finally, they compiled a portfolio of their work to serve as both a resource during the hearing and as a summative assessment for the experience. Several class periods and significant out-of-class time were used to accomplish these goals. Students received a brief introduction to PowerPoint, but most of the software instruction was provided during three brief (5–10 min) lectures. Students were given 10–12 min to present their case, including not more than eight to ten slides. They could also include five to six extra slides to answer potential questions posed by senators following their presentations or during the discussion on the second day.

Senate Subcommittee Hearing

On the first hearing day, the instructor reminded the senators of their responsibility to run the hearing. The instructor's role was simply to facilitate the technology and make sure that each person remained in their role during the hearing. Senators were told to "run as formal a hearing as possible."

Each special interest group used PowerPoint to present their position and discuss their principal points. The extent to which students were comfortable presenting to

their peers varied. Several groups presented compelling arguments, while other presentations led to a barrage of clarifying questions by the senators. In general, the senators followed each presentation with two or three clarifying questions. Introductions, presentations by each of the six groups, and transition from one group to the next took almost one entire class session (90 min).

After class, the senators met the instructor to discuss their responsibilities. The senators were charged with reviewing what each special interest group had said and developing follow-up questions to ask each group. The senators were able to juxtapose groups against one another by facilitating a general discussion around a particular topic (such as ideas for legislation). For example, senators might ask the same questions to two groups (e.g., the Monsanto Corporation and the Environmental Defense Organization), allow them to respond, and then open the topic up for discussion among all the groups.

The second day of the hearing was much more dynamic and lively than the first. While the students formally presented their ideas on the first day, the second day was intended to generate a debate atmosphere and to challenge students to articulate and defend their positions. The senators recalled each group to ask clarifying questions about the previously presented arguments. If conflicts arose between the groups, then the senators would encourage each group to justify their positions. Many students relied on both the extra PowerPoint slides they created or referred to the articles and book chapters they had copied. In addition, their portfolios served as a valuable resource, which enabled them to find and organize the papers and supporting information they were using with relative ease. Finally, the senators had several more open discussions to present issues to the groups and to see where the deliberations led. When the class period was over, the senators thanked the groups and told them that they would present their final decision during the next class period. The instructor met again with the senators to make sure they understood their responsibilities. The senators wrote a two-page response to the three driving questions and decided which special interest group(s) "would have a hand in writing the future legislation" regarding the Bt genes in corn.

Senate Subcommittee Statement and Debrief

In the next class, the senators presented their findings and decisions regarding each of the driving questions. The class then discussed the outcomes from the perspectives of their special interest groups. Finally, the students were asked to drop their roles and engage in a reflective discussion about the entire experience. To prepare for this discussion, each of the students had written an individual evaluative reflection that addressed the following questions:

1. Overall, what did you think of the experience?
2. Currently, how well-informed do you feel about the topic?
3. How did your views regarding Bt Corn change during our experience?

4. What are your current opinions regarding Bt Corn specifically, and genetically modified foods in general?
5. How has this experience changed your view on the application of scientific knowledge to policy, political, and social decisions?
6. Are there any other comments or suggestions you would like to make?

These questions served to guide the discussion and enabled students to reflect on their experience prior to the in-class discussion.

In an effort to represent the experience in its entirety, the class developed a group concept map of the Senate hearing. First, the students worked in their special interest groups, or as senators, to develop a concept map that represented the issues that were of primary concern to their group. These maps were drawn on 2 ft by 3 ft pieces of newsprint. For example, the Environmental Defense Organization identified ecological concerns, economic concerns, human safety concerns, EPA/FDA, recommendations, resistance, benefits of Bt Corn, and the goals of Bt Corn as the areas of greatest concern to their group during the experience. Special interest groups then provided more detail in each of those areas on their maps by linking other concepts or topics to their initial issues. Once each of the special interest groups had completed their maps, the class was instructed to create a single large concept map by placing their individual maps relative to one another on the classroom wall (Fig. 2). This combined concept map was revised over several iterations and conversations. Once finished, it was used as the centerpiece for a discussion about the nature of science, primarily how scientific issues are shaped by economic, political and social forces.

Unpacking the Experience

Senate Hearing

The Senate Subcommittee hearing structure forced students to explore, appreciate, and articulate the perspectives of their special interest group, as well as develop a solid understanding of the science behind Bt Corn. Initially, students had to explore their special interest group and develop an understanding of what their position might be on Bt genes in corn. This research was done primarily through online resources. Some special interest groups had fairly specific information on their website that was applicable to Bt Corn and the hearing, whereas other students needed to infer what their particular group's position might be, based on the perspectives or mission of the group. Once students identified their group's position on the issues at hand, the students began to search the literature for relevant information and research to build their case.

On the first day of the hearing, the special interest group presentations served to create a foundation for a more lively debate on the second day of the hearing (Table 2). The presentations were somewhat formal in nature and seemed to reflect

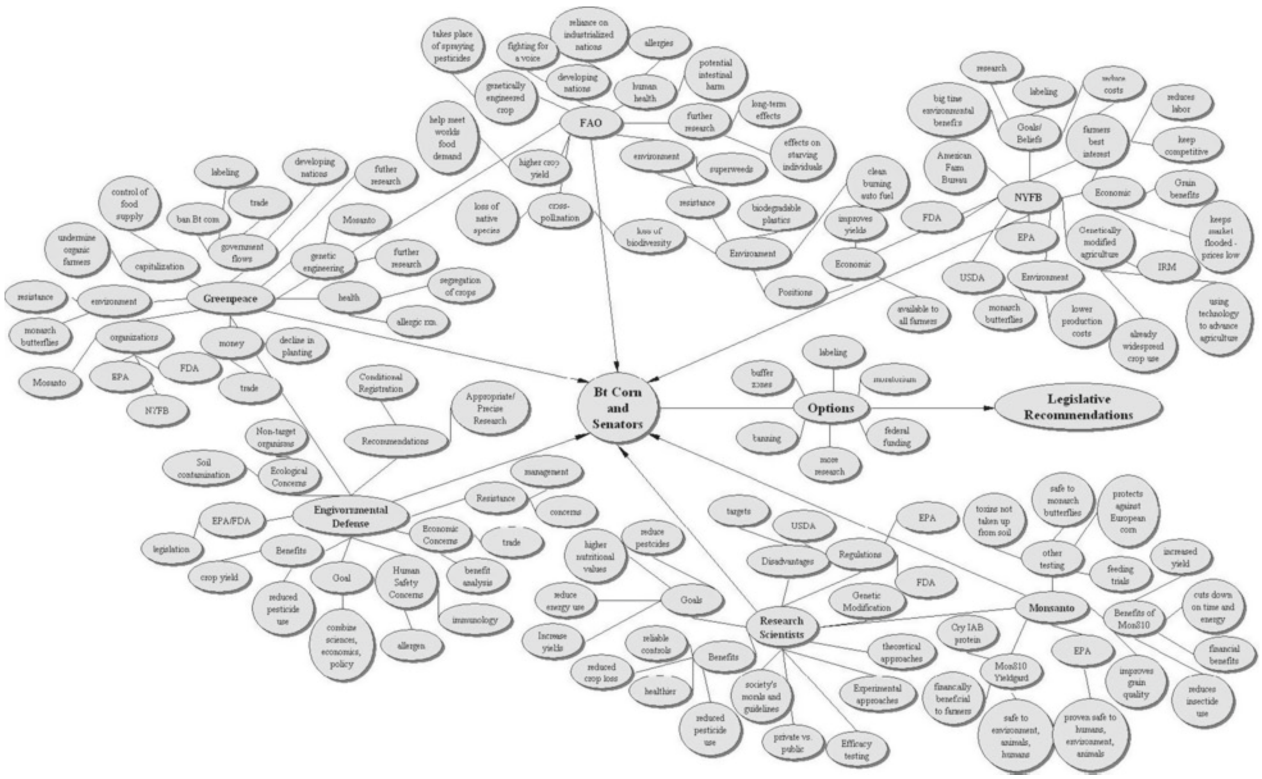

Fig. 2 Simplified electronic version of the class concept map of Senate Subcommittee hearing on Bt genes in corn

Table 2 Primary arguments made by special interest groups during the first day of the hearings

	Special interest group	Primary arguments
Pro	*Monsanto Company*	The Monsanto strain of Bt Corn was tested for 20 years before EPA approval and poses little risk
		Our Bt Corn product, YieldGard, results in a greater yield per acre
		Bt Corn reduces amount of insecticide used
		The use of Bt Corn improves grain quality
	NY State Farm Bureau	Bt Corn is beneficial for farmers
		A moratorium on Bt Corn would be damaging economically
		The impact on butterflies is negligible
		There are a number of environmental and economic benefits
	Genetic research scientists	Bt Corn is a reliable control of target pests
		Bt Corn has reduced crop loss and pesticide use
		Bt Corn has increased yields
		Bt Corn has provided farmers with the ability to use marginal land
	UN Food and Agriculture Organization	Bt Corn has devastating effects on native species
		Use of Bt Corn results in a loss of biodiversity
		Much of the impact of Bt Corn is within impoverished countries
	Environmental Defense Organization	The originally claimed benefits in the reduction of pesticides proved to be misleading
		Research on the impact of Bt Corn on butterflies was poorly designed and implemented
		Bt research on impacts was conducted on aquatic animals instead of animals actually affected by corn pollen
Con	*Greenpeace*	Bt kills Monarch butterflies
		There are concerns about transfer from plant chromosomes to soil bacteria
		Use of Bt Corn increases cost for farmers
		Use of Bt Corn decreases trade domestically and internationally
		Control of food supplies will be in the hands of a few large companies
		An increase in large-scale farming has led to rural unemployment

a certain amount of competition among the groups. All of the groups made good to excellent presentations. They were clear, straight-forward, and organized in a logical manner. The senators took notes throughout the hearing and tended to ask two or three clarifying questions at the end of each presentation.

The following day, the senators asked the follow-up questions. This required students to have a solid understanding of the material they were presenting and the primary literature they were using to support their case. The basis for students' presentations came in a number of different forms. Much of the information had been distilled into the PowerPoint presentations themselves. More detail was available within the copies of manuscripts that the students included in their portfolios. These research papers and the figures within were often at the heart of particular arguments. For example, the New York State Farm Bureau used a figure that documented a national decline in herbicide use due to the introduction of Bt hybrids in 1997. The senators asked a number of clarifying questions about this figure, in addition to asking about its source. This "cross-examination" was a great example of how the students were forced to explain their assertions and how the senators attempted to tease apart the arguments of each special interest group. For example, at one point during the second day, the senators asked Greenpeace to restate their position about the negative effects of Bt Corn in light of what Monsanto representatives had argued about the safety of their product.

> Senator: We would like to hear from both Greenpeace and Monsanto again. On Tuesday, you (Greenpeace) talked about the impacts that Bt Corn has had on butterflies and so forth. We'd like you to respond to what you've heard from Monsanto thus far. Have your views changed?
>
> Greenpeace: We feel that the science behind Monsanto's statements is questionable. We don't know how butterflies or plants in the surrounding fields and such will be affected.
>
> Monsanto: I'd like to respond.
>
> Senators: Go ahead.
>
> Monsanto: We based our position around the strain MON 810. Much of the research done on Bt Corn was done with other strains. These are very different and less safe that MON 810. There've been 20 years of testing on this strain by the EPA with no environmental concerns. Some of the other strains may pose a risk and, as we said, they'll likely be withdrawn from the market.

This interaction gave Monsanto a chance to reiterate its strongest point that their argument was based on MON 810, a strain that has, so far, been shown to be safe. When the argument started going back and forth, the Monsanto representatives stated repeatedly that they were referring to MON 810 and not some of the other strains.

Senate Subcommittee Statement and Findings

The three senators used what they learned over the course of the 2-day hearing to craft their statement, which was guided by the hearing's three driving questions. First, the subcommittee found that there were "several legitimate concerns regarding the use of Bt-genes in corn." These included the possibility of Bt genes acting as a food allergen, adverse effects on malnourished children, inadequate labeling,

impacts on non-target organisms such as the Monarch butterfly, and the loss of native crops due to cross pollination. Second, they recommended "labeling of genetically-modified products (at least up to primary goods), provisions for a buffer zone surrounding Bt Corn fields (so that cross-pollination and resistance may be slowed or even prevented), and a required registration process." Finally, the senators decided that more research was needed, which should be especially focused on the:

> consequences of using Bt Corn, whether it is beneficial or detrimental to the environment, surrounding ecosystems, and human consumption.
>
> In order to meet the interests of all groups involved, including environmental organizations, company suppliers, farmers and individual states, we have found that the best solution would be to provide funding for further research, and regulate fields so that potential concerns may be avoided as much as possible.

The Senators did an excellent job of synthesizing a tremendous amount of information and making recommendations that recognized the complexity of this issue.

Concept Maps

The Senate Committee Hearing created a real-world context that enabled these future teachers to develop more robust conceptions of the nature of science and the complexities of controversial environmental issues applied within political and social arenas. The students' first concept map, drawn prior to the Senate Subcommittee hearing, represented their initial conceptions of science. It focused almost exclusively on the science disciplines and specific areas within each discipline (Fig. 1). After the senate Subcommittee hearing, a similar collaborative activity led to the creation of a "new concept map" (Fig. 2). This concept map focused on the nature of their experience throughout the hearings. By creating this map, students were able to capture, articulate, and discuss the epistemological complexities embedded within this single environmental issue and discuss how the Senate hearing changed their conceptions of science more generally. Science was now seen as cutting across social, economic, political, and often, very personal boundaries.

> Upon completion of the hearing and evaluating each issue, my views regarding the application of scientific knowledge to policy, political, and social decisions have changed. As a scientist in training, I realize the impact fundamental research can have on such policies… in addition, politicians need to evaluate this work thoroughly so that they may make the best overall legislative decisions… Scott – Greenpeace

This shift in thinking made it very challenging for the senators to arrive at answers to the driving questions for the class. Consequently, the senators invested a significant amount of time in preparation for the hearing's second day, and they had a real "need to know" when asking the different groups follow-up or "clarifying" questions. The driving questions served to both inform and organize the questions asked by the senators.

Student Experience

At times, the nature and structure of the role-play experience caused the students to truly struggle in a variety of ways. A primary goal of inquiry teaching is to create a learning environment in which students are challenged, yet have the supports they need to be successful (Crawford 2000). Some students struggled with the fact that their position within the role-play experience did not necessarily match their personal position on the issue. This experience provided an opportunity for them to consider views other than their own, while re-examining their own views on this issue at the same time. More importantly, the lack of lectures on the detailed science content behind Bt Corn forced students to develop their own understandings. The depth and accuracy of these understandings manifested themselves in their presentations and throughout the hearing. The students often had to explain concepts such as transmission or cross-pollination in considerable detail. The understandings that they demonstrated were usually far beyond the basic scientific information covered during the class.

To achieve success, students had to construct and articulate logical and rational arguments. Not surprisingly, some of the students were better able to communicate their ideas than others, but all of the PowerPoint presentations reflected a clear line of thought or argument that was grounded in relevant evidence. The nature and origin of the evidence varied from group to group and became of concern to the senators at various points during the hearing. For example, some of the evidence used by Greenpeace came from newspaper articles, whereas the New York State Farm Bureau used EPA sources, Monsanto, and other research studies published in peer-reviewed journals. By asking each group pointed questions about their sources, the senators were able to better understand the types of sources that were grounding their arguments.

The students developed robust interdisciplinary perspectives about the issues surrounding Bt Corn. There were several advantages in terms of a group responding to the senators in the context of "competing" with the other special interest groups. This sense of competition required each group to not only argue their own position, but also to understand, appreciate, and evaluate the position of the other groups, so that they could frame their arguments in a manner that was compelling to the senators. As a result, both the senators and special interest groups came to see the issues surrounding Bt genes in corn as embedded within cultural, political, economic, and social agendas.

> The benefits and disadvantages of Bt Corn certainly became a large part of how I perceived the issues. As a Senator, I had to not only keep in mind the interests of my state, but also and more importantly, keep an open mind to how it affects people of different groups, whether they are national, cultural, or even part of a minority. Partaking in this role thus allowed me to make an informed decision about my personal position on the issue. I experienced a lot of fluctuations before making a conclusion, finding it difficult to decide whom to take seriously with so many conflicting findings. Kaitlin – New York State Senator

The role of this student as a senator is clearly reflected in her response. How Bt Corn affects the lives of real people is of central concern to her. Her response also reflects the fact that different groups of people can be affected very differently by

a particular policy or piece of legislation. Most students came to appreciate the impact that scientific issues can have on our lives.

> The Senate Hearing on Bt Corn integrated science and technology while at the same time addressing ethical and political issues. Science can be applied to every aspect of society and is used to make decisions that affect all our lives. As a political science major, I recognize the importance of a scientific background in our nation's leaders. Technology and science go hand in hand, but science is diverse and can affect people's lives in different ways. Erica – Food and Agriculture Organization of the UN

Student Understandings

The role-play experience and the follow-up discussion helped students to better understand the nature of science and scientific knowledge. Students saw science as much more than simply a body of knowledge. The shift in their views on science reflected their broadened outlook and understanding of the impact of science on the world.

> Science is much more a part of this world than simply the disciplinary area. It is an interdisciplinary perspective that intertwines all aspects of life. Julie – New York State Farm Bureau Representative

The concept map that the students made at the end of the semester best represented the way the students came to view science and the application of scientific knowledge to environmental issues. The development of the group and whole-class concept maps enabled the students to see the entangled and interconnected nature of the issues at hand. The question of genetically modified food, and Bt Corn specifically, served as useful examples of how technological innovation can have far reaching social and political ramifications.

> The concept map did a nice job capturing my views regarding the application of scientific knowledge to policy, political, and social decisions have changed. As a scientist in training, I realize the impact fundamental research can have on such policies. However, I had never looked at it through the eyes of a politician, until now. So much research is done in this world on an infinite number of elements, that often times similar research is going on somewhere else that completely contradicts one's findings. This does not mean that one's work is insignificant. What it does mean however, is that politicians need to evaluate this work so that they may make the best overall legislative decision. Kaitlin – Senator

Kaitlin did a nice job highlighting the fact that there are often competing research agendas around controversial topics.

The students developed a greater appreciation about why some political groups may never agree on a particular issue. However, decisions still need to be made and policy makers may or may not have the time to hear every side of a particular story.

> This whole process has changed my opinions on scientific knowledge and its entanglements with public policy and environmental decisions. I think scientific research is very important, but that it must look at some of the social ramifications it can have. Not everyone is going to agree and support all research. Mike – Monsanto Representative

The role-play simulation helped students to see that politics is much more than how laws are made in Washington, D.C. Politics and political agendas refer to groups of real people who share common concerns and agendas. At times, such stakeholders might organize themselves into special interest groups in order to exert significant influence over legislation and funding. Having a diverse set of special interest groups assisted most students in developing an appreciation for the diversity of legitimate perspectives on a particular issue.

Finally, the students came to see how issues such as Bt Corn touch their own lives and the lives of people in their community. As one group represented the New York State Farm Bureau, students increased their awareness of how genetically modified foods affect local farmers. We were fortunate that one of the students in this group grew up on a New York state farm. She was able to talk to her father about the issues presented. This provided an additional level of authenticity to her experience.

Implications

The Senate Subcommittee hearing on Bt genes in corn facilitated these students in expanding their conceptions of science and helped them to develop a greater appreciation for how science is applied to environmental problems. Environmental role-play simulations are a powerful way to put students in a context that challenges them on many levels. The context forces them to explore the science behind an issue, understand the social and environmental ramifications of a particular technology, and develop not only an appreciation for the topic, but an ability to make a convincing, logical, and coherent argument to their peers.

This simulation role-play falls within the realm of what Zeidler, Sadler, Simmons and Howes (2004) and others refer to as the *socioscientific issues domain* (SSI) of science education. This movement refers to scientific topics that lead to the "consideration of ethical issues and construction of moral judgments about scientific topics via social interaction and discourse." Issues that cut across these constructs can powerfully motivate students. More importantly, bridging the scientific, ethical, moral, and often very personal boundaries within which students operate can lead to greater and more broadly defined scientific literacy.

Experiences such as a simulation role-play around a socioscientific issue are extremely valuable for future teachers. Having a broader view of science and the application of scientific knowledge will help them think about ways to help their future students develop an appreciation for the nature of science and the real-world applications of science. Additionally, the unit incorporated a wide variety of teaching strategies and topics that are currently of interest in science education: simulations, role-playing, driving questions, oral presentations, technology integration, portfolios, reflection, and concept mapping. The ultimate goal of this experience was to model the structure and nature of an inquiry-based unit, which would aid these future teachers as they design lessons and units for their own classrooms.

Exploring Other Contexts and Questions Using Simulations

The same approach, context, and structure can be used in many contexts. I have engaged students in Congressional Subcommittee hearings on the Endangered Species Act, Genetic Testing, and the establishment of hog farms. The core aspects of this approach are the driving questions, the nature and focus of the student groups, and the level of responsibility given to the students. First, the driving questions presented earlier only need to be modified in terms of the topic. The final question of "what additional research or legislation might be useful" is the primary framework for student inquiry and their presentations. Everything they do, including addressing the other two questions, is in pursuit of this question. Second, the nature and structure of the student groups are very important. Students should be provided with adequate resources to understand the focus of their groups and to conduct their research. Furthermore, the stakeholder groups chosen for the hearing should accurately represent the diversity of perspectives on the issue to be discussed. Finally, the students should have as much autonomy and responsibility as possible. This will vary widely depending on the class, subject, and context, but the goal should be to enable students to develop presentations that reflect their own work and perspectives.

Several other curricula provide students with opportunities to role-play within a simulation. The *Environmental Issues* section of the EnviroSci Inquiry project at Lehigh University has several units that engage students in extended role-play simulation projects (EnviroSci Inquiry 2008). For example, the Abandoned Mine Drainage module involves students examining the nature and history of abandoned mine drainage issues in Pennsylvania. Students build on prior experiences and use a range of technologies to explore data relevant to their investigation. This experience culminates in a student debate focused on how best to clean up streams and rivers across Pennsylvania that are affected by abandoned mine drainage.

Hog Wild! and the Potential of New Technologies

Structures for science and environmental role-play simulations have even greater potential in the light of new information and communication technologies. One example is a recently developed curricular module entitled HogWild! (Wilson and MaKinster 2008). HogWild! is an interdisciplinary simulation that engages students in a town council hearing on the proposed establishment of a hog farm in a local watershed. After brainstorming the potential effects of a new hog farm, students use Google Earth to visit each of the stakeholders and then use ArcGIS software to create maps that support their positions. The HogWild! curriculum has been used in science courses for preservice teachers, high-school environmental science, and in a middle school by a social studies and English teacher. Each teacher had different conceptual goals and emphases; however, they were guided by the same set of goals and curricular expectations.

- What are the costs and benefits of establishing a hog farm in your watershed?
- Who are the stakeholders?
- What is your group's position on establishing a hog farm?
- How can you use maps and related data to support your position?
- How can you most effectively communicate your position?
- Should Hatfield Pork establish a new hog farm in your watershed? (hearing)
- What have we learned about this issue and what are some solutions to the issue?

Other new technological and assessment tools, such as blogs, wikis, and podcasts create additional pedagogical opportunities. Blogs can be used as a means to communicate with experts in the field or as a means for student groups to capture their research or findings. Wikis enable individual students or student groups to collaboratively contribute to a document that serves to reify their position on a particular issue. For example, in the HogWild! curriculum, each student group (Hog Farmers, Farm Bureau, EPA, Tourism Bureau, etc.) could develop a Wiki that serves to articulate their position and incorporated images, videos, graphs, and other information in support of their arguments. Finally, audio or video podcasts are yet another means by which students can share their ideas. The technology necessary is becoming increasingly accessible, both in schools and at home. Each of these approaches has its own set of challenges; however, there are free online services for blogs (e.g., Blogspot 2009) and Wikis (e.g., PB-Wiki 2009) that are being used by an increasing number of educators.

Environmental Inquiry

Ultimately, this use of role-play simulations informs the ways in which environmental and science educators ask students to explore environmental questions and, in particular, what it means to engage in *environmental inquiry*. Too often, science investigations are cast or discussed under the heading of environmental education, simply because they have relevance to environmental issues.

Environmental inquiry must enable students to examine the scientific, social, political, economic, and ethical dimensions of a particular issue. Such a lesson or unit should enable students to see and discuss each of these dimensions simultaneously. Ideally, students should encounter situations where they have to wrestle with diverse perspectives and apply them to a given situation; however, such an approach can be applied anywhere along the teaching continuum from lecture to open inquiry. When environmental issues are considered from only one or two of these perspectives, it is difficult, if not impossible to identify environmentally sound solutions that address or acknowledge the needs and concerns of everyone involved. As environmental educators, we must take the time to step back and reveal the hidden assumptions and dimensions within an issue in ways that help our students become not only better informed, but also better able to contribute to environmental solutions in their own schools, communities, and the world.

References

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International Journal of Science Education, 22*(7), 665–701.

Aubusson, P., Fogwill, S., Barr, R., & Perkovic, L. (1997). What happens when students do simulation role-play in science? *Research in Science Education, 27*(4), 565–579.

Bessin, R. (1999). *Bt-Corn: What is it and how it works*. Retrieved October 31, 2002, from http://www.uky.edu/Agriculture/Entomology/entfacts/fldcrops/efl.30.htm

Blogspot. (2009). *Blogspot website.* Retrieved March 22, 2009, from https://www.blogger.com/start

Council for Environmental Education. (2003). *Project WILD: K-12 curriculum and activity guide*. Houston, TX: Council for Environmental Education.

Crawford, B. A. (2000). Embracing the essence of inquiry: New roles for science teachers. *Journal of Research in Science Teaching, 37*(9), 916–937.

EnviroSci Inquiry. (2008). *Abandoned mine drainage module*. Retrieved October 5, 2008, from http://www.leo.lehigh.edu/envirosci/watershed/riverexp/mine/index.html

Harwood, W. S., MaKinster, J. G., Cruz, L., & Gabel, D. (2002). Acting out science: Using Senate Hearings to debate global climate change. *Journal of College Science Teaching, 21*(7), 442–447.

Losey, J. E., Rayor, L. S., & Carter, M. E. (1999). Transgenic pollen harms Monarch larvae. *Nature, 399*(6735), 214.

McComas, W. F. (1996). Ten myths of science: Reexamining what we think we know about the nature of science. *School Science and Mathematics, 96*(1), 10–16.

McKeachie, W. J. (1994). *Teaching tips: Strategies, research and theory for college and university teachers*. Lexington, KY: D.C. Heath.

Nelson, C. E., Nickels, M. K., & Beard, J. (1998). The nature of science as a foundation for teaching science: Evolution as a case study. In W. F. McComas (Ed.), *The nature of science in science education*. Dordrecht, Netherlands: Kluwer.

PBwiki. (2009). *PBwiki website*. Retrieved March 22, 2009, from http://pbwiki.com

Pennock, M. T., & Bardwell, L. V. (1994). *Approaching environmental issues in the classroom* (pp. 1–23). Ann Arbor, MI: University of Michigan.

Project WET. (2003). *Project Wet: K-12 Curriculum and activity guide*. Boseman, MT: The Watercourse.

Shelton, A. M., & Roush, R. T. (1999). False reports and the ears of men. *Nature Biotechnology, 17*(9), 832.

Shulman, L. S. (2000). From Minsk to Pinsk: Why a scholarship of teaching and learning? *The Journal of Scholarship of Teaching and Learning, 1*(1), 48–52.

Webb, D. (2002). *Role-playing: A teaching strategy*. Retrieved July 11, 2003, from http://condor.admin.ccny.cuny.edu/~cb6879/spring2002/davidpaper.htm

Wilson, C., & MaKinster, J. (2008). *HogWild!: An interdisciplinary unit exploring the environmental issues surrounding the establishment of a hog farm in the Finger Lakes Region.* Retrieved from http://fli.hws.edu/gitahead/hogwild/teacher.html

Zeidler, D. L., Sadler, T. D., Simmons, M. L., & Howes, E. V. (2004). *Beyond STS: A researched-based framework for socioscientific issues education.* Paper presented at the National Association for Research in Science Teaching, Vancouver, British Columbia.