

Investigating Reformulated Gasoline in an Issue-based Environmental Science Course

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Abstract: Project- or case-based education is an excellent means of providing students with hands-on, inquiry-driven educational opportunities. Developing effective course units, however, requires rethinking pedagogical strategies and sometimes teaching material with which we are unfamiliar. This paper describes a case-based unit on reformulated gasoline that was used in an introductory environmental science course for Honors students, most of whom were not science majors. In the unit, students were asked to wrestle with a conceptually difficult but very relevant issue: “Should the EPA have waived the reformulated gasoline requirement for the Milwaukee area in the summer of 2000?” They were required to learn a variety of scientific concepts, as well as to understand the process of scientific research. Student assessment indicates that they were frustrated by the confusing and contradictory nature of the topic, but also found value in working through the complex issue.

Key Words: Case Study, Environmental Science, Inquiry-based Instruction, Reformulated gasoline

INTRODUCTION

In 1995, a national convention on science education was held at the National Academy of Sciences, co-sponsored by the National Science Foundation and the National Research Council. The most critical goal identified in that convention was that “all students should have access to supportive, excellent programs in science, mathematics, engineering, and technology, and all students should acquire literacy in these subjects by direct experience with the methods and processes of inquiry” (NRC 1996:4). Such a conviction requires rethinking traditional science education. In particular, it requires new approaches to teaching: “cooperative learning, project-centered classes, investigation-oriented laboratories, courses centered on case studies, self-paced instruction, techniques that solicit immediate feedback on teaching and course content, etc. These approaches help students to analyze, criticize, and communicate.... They help students take responsibility for their own learning” (NRC 1996:22). Rothman and Narum (1999) document that over the last decade, science education has been actively involved in a variety of reforms designed to accomplish that goal. More importantly, they document that the reform efforts are having a significant, positive effect on student learning in science.

Many faculty members, however, resist making the types of innovative reform efforts that reports such as those cited above encourage. In courses for science majors, the challenge is often in finding a balance between covering the content that is the foundation to the discipline and encouraging inquiry necessary for success in the field. In courses for non-science majors, coverage of a particular body of content is less of a concern, facilitating a less traditional course structure (HHMI:29). However, even in non-majors courses, instructors may be reluctant to deviate from a traditional course structure for a variety of reasons. For example, instructors may not be aware of alternative teaching techniques, may be hesitant to relinquish ‘control’ in the classroom, or may not feel they have sufficient expertise to facilitate a case or problem-based course structure. In addition, students often feel more comfortable with a traditional class format and are reluctant to take a more active role in the classroom (Narum 1997:20).

In the fall of 2000, I taught an introductory course in environmental science for Honors students at Carroll College. For a variety of reasons (outlined below), I decided to move away from the typical survey-course structure to one centered around three units, each focused on investigation of a particular local problem or issue. This paper describes how the first three units were structured, as well as how the students responded

to the non-traditional format. This is done not to provide an exemplary model of the “perfect” course (which it clearly was not), but rather to present a realistic picture of efforts at curriculum reform. The objectives in this paper are: 1) to share resources and strategies for designing a unit centered on reformulated gasoline and ground level ozone, and 2) to share the successes and concerns associated with teaching a student-driven, case-based instruction unit. It is hoped that this may stimulate others to try a new approach to teaching. Although pitfalls were encountered along the way, the students in this course wrestled with a real, science-based issue. In the process, they developed skills and confidence that will help them be more successful in facing other similar issues, not only as students but as informed citizens.

THE SITUATION

Carroll College is a primarily undergraduate institution with approximately 2000 undergraduate students. Students in the Honors program are admitted by invitation, based on academic success at the high school level. They are required to take six courses from a menu of designated Honors courses (such as this one) and to complete a Senior Honors Project in order to graduate with Honors from Carroll. Students in this introductory environmental science course ranged from sophomores to seniors. Only one of the twelve students in the class was an environmental science major. The other students were majoring in a diverse array of fields including History, Computer Science, Business Administration, Education, and Art. Many of the non-science majors were ambivalent (at best) about taking a science course. They had registered for the course because it: 1) fulfilled a requirement in our general education curriculum, 2) was an honors course, and 3) sounded more interesting than other science alternatives.

The course satisfied requirements of the college-wide Liberal Studies Program, in the areas of “Science as a Way of Knowing” and “Understanding the Natural World”. It also satisfied departmental core requirements for the Environmental Science Major. For these reasons, the specific course objectives (Box 1) were externally defined. One of the most important forces this exerted on the design of the course was that it really needed to teach *science*. We observed that students taking courses in environmental science learn very little about what science is and how science is done; it was essential to counter that trend in this course. Because it was an Honors course, the students should have an opportunity for self-directed learning about real environmental issues. The course also needed to involve research and critical thinking. Finally, it was important that each unit connect lecture/class activities to laboratory activities in a meaningful way.

Box 1: Course Objectives

At the conclusion of this course, students should be able to:

- Demonstrate an understanding of the physical and biological worlds and methods of investigating them that is sufficient to assess and use scientific evidence in making intellectually responsible decisions.
- Assess various societal impacts and implications of global environmental change.
- Measure environmental quality in various qualitative and quantitative ways.
- Demonstrate an ability to use modern methods to access, analyze, interpret, and communicate effectively both qualitative and quantitative information.
- Cultivate a set of personal values and attitudes concerning the environment that will motivate oneself to actively address environmental problems and effectively participate in their solutions.
- Demonstrate competency in written and oral communication, use of information technology, critical thinking, and understanding contemporary relevance.
- Demonstrate increased self-confidence with respect to understanding and using scientific information, including an understanding of the role of uncertainty in science.

The issue selected for the opening unit of the course centered on the question: “Should the EPA have waived the reformulated gasoline requirement for the Milwaukee area in the summer of 2000?” The question was chosen for a variety of reasons. First, the issue had immediate relevance to the students. They had a stake in understanding the rationale behind the EPA’s decision. Students had watched gasoline prices soar to over \$2.00 per gallon throughout the summer. State and local governments had initiated legal action against the EPA for not waiving the RFG requirement. Media coverage was full of contradictions, finger pointing, and questionable information.

Second, the issue involved a great deal of science. Students needed to understand the basics of combustion chemistry, the composition of gasoline, how air pollutants are formed, and what impacts such air pollutants have on plants and animals. They also needed to understand how scientists carried out the research upon which policy-makers were basing their decisions. By pairing in-class activities with field research on the effects of ground-level ozone on milkweed plants, students directly experienced the process of scientific investigation, from posing a research question through analyzing and presenting data and drawing conclusions.

Third, the issue had political and social ramifications. Students had an opportunity to see first-hand how political decisions were made. They could also see the economic ramifications of those decisions – not just at the gas pumps but also on agricultural systems, etc. This provided opportunities for many of the students in the class to have a greater sense of ownership of the issue by allowing them to draw connections to their experiences in other courses, including their academic major.

Finally, and perhaps most importantly, the issue had no clear answer. This meant that students would be pushed to critically evaluate the available data and arguments and to draw their own conclusions from that analysis. The ambiguity of the problem did not become apparent until well into the study. It was a vivid example of how decisions are made in spite of scientific ambiguity.

UNIT STRUCTURE

The course was organized in two 2-hour blocks for lecture/discussion and one 3-hour laboratory each week. On the first day of class, the issue was introduced and students were given the opportunity to develop a list of what they felt they needed to understand in order to answer the question posed. They also brainstormed potential sources of that information. These discussions guided the development of the subsequent four weeks of the course. Sessions included lectures, guest speakers (a Wisconsin Department of Natural Resources Air Quality Expert and the Waukesha County Executive, as

well as other environmental science professors), group presentations, and class discussions. For the group presentations, students were divided into groups of three. Each group was charged with researching and presenting to the class information on one of the following topics: air quality regulations; ethanol and MBTE; the supply and distribution of reformulated gas; or the economics of reformulated gas. Class sessions were supplemented by readings from the National Academy of Sciences report on reformulated gasoline (NRC, 1999) and readings from a general environmental science textbook (Cunningham and Saigo, 2001). One class session was spent touring a local vehicle-emissions testing station.

In the laboratory portion of the unit, students investigated the effects of ground-level ozone on milkweed leaves (*Asclepias syriaca*; KanCRN 1997; Spring Harbor, 2000). Once students became familiar with identifying ozone damage (Figure 1), they developed hypotheses regarding the relationship between the level of ozone damage on leaves and variables such as whether the plants are growing in urban or rural settings, near or far from major roadways, etc. These hypotheses were further developed into formal research proposals. Proposals were peer-reviewed, and then returned for revisions. Then the class spent five weeks visiting milkweed patches in various locations collecting data. These data were statistically analyzed and each group presented their research project in a class symposium. Each group also wrote a paper in formal scientific format.



Figure 1: Ozone Damage on Common Milkweed (*Asclepias syriaca*). Bioindicators such as milkweed are used to monitor ground-level ozone levels within a given area. Ozone causes formation of black stippling on the leaves of the plant. Photograph courtesy of Kathryn Yurkonis.

Various measures of student learning were incorporated into evaluation of the unit. The group report on reformulated gasoline was assessed for both quality of the presentation and understanding of the critical concepts (class mean = 22.5 of 25 points). At the end of the unit, students prepared a written paper or project focused on their answer to the original question posed (“Should the EPA have waived the reformulated gasoline requirement for the Milwaukee area in the summer of 2000?”). Many students completed a traditional “term paper” type report, but others chose to format their response as a brochure or booklet with a more educational focus. The class mean on this assignment was 42.5 of 50 points. Students also took a written examination covering the basic scientific concepts. The class mean on the exam was 58.9 of 70 points. Assessment of the laboratory portion of the unit was based on quality of the preliminary research proposal (mean = 18.4 of 20 points), the final oral presentation (mean = 18.5 of 20 points), and the final written report (mean = 26.4 of 30 points).

THE STUDENTS’ RESPONSE

Students’ course evaluations indicate that the unit achieved, at least in part, the learning objectives established for the unit. Ten of the twelve students in the course (83%) responded that each of the following four statements was either accurate or somewhat accurate:

- The reformulated gas unit helped me learn more about environmental science.
- The reformulated gas unit was appropriate for an honors level course.
- The milkweed/ozone study helped me to learn more about scientific research.
- The milkweed/ozone study was appropriate for an honors level course.

When asked to evaluate to what extent each student believed s/he accomplished particular course objectives, the results were similarly positive. Eleven of the twelve felt they were able to apply research methods to the analysis, synthesis, and evaluation of environmental information (fully achieved = 5, mostly achieved = 6). Ten of twelve felt they had cultivated a set of personal values and attitudes concerning the environment that will motivate them to actively address environmental problems and effectively participate in their solutions (fully achieved = 6, mostly achieved = 4). Most students also felt that the course had helped develop increased self-confidence with respect to understanding and using scientific information, including an understanding of the role of uncertainty in science (fully achieved = 2, mostly achieved = 7). The lower proportion of students indicating the objective was fully achieved indicates this was not accomplished as successfully as the others. Written comments from student evaluations (Box 2) reflect the students’

frustration and confusion, but also indicate that they perceived value in their struggle with the material.

Box 2: Comments from Student Course Evaluations

- *Honestly, for the first few weeks of the course, I was lost. I found this to be an uninteresting unit to begin with until a DNR representative came in and explained everything in an informative, easy to understand manner.*
- *We needed more background information from the instructor.*
- *The problem we were trying to address was more political than scientific.*
- *It was no doubt a challenging unit, bringing a lot of issues together. Maybe it would be more effective at the end of the semester.*
- *I was very confused. I think I needed more of a definitive answer to some of my questions.*
- *Was difficult as it was with such a new subject to study. At times, it seemed that there was way too much information because we had trouble deciding what was true/untrue or important/unimportant.*
- *More substantial information, if possible.*
- *Confusing*

REFLECTIONS AND CONCLUSIONS

“Confusion” was a major hurdle for the students, as reflected in their comments on the course evaluations. They were frustrated at the level of uncertainty and apparent contradictions in the research they reviewed. This was a particular challenge for those students who began the course feeling uncomfortable with science. The students’ confusion was actually both positive and realistic. The data *are* contradictory and incomplete. Political maneuvering *does* play a significant role. This *is* the real world. Many of the students came to appreciate these realities. However, the frustration tended to set a negative tone for the rest of the semester. Were I to teach the course again, a unit with this level of complexity and ambiguity would be moved to the end of the semester. An initial focus on smaller-scale, more concrete issues would allow students to build skills in critical analysis and establish their self-confidence with the vocabulary and processes of science incrementally throughout the semester, and then reinforce their growth and learning by tackling a very difficult issue as the capstone project.

The reflective judgment model of adult intellectual development developed by Kitchener and King (1981; cited in King, 1992) suggests that people

in early stages of intellectual development tend to view issues in terms of black/white dichotomies. Subsequent developmental stages begin to recognize ambiguity in issues, to the point where no decision or action is possible because the uncertainty is too overwhelming. At an advanced level of development, however, one is able to critically evaluate the evidence in light of the uncertainty, and select the most appropriate action or response based on that critical analysis. The class clearly followed this developmental sequence throughout the reformulated gasoline unit, with various students reaching different developmental “end-points” during the semester. Their papers reflected this variability, with some students conducting extensive analyses and drawing conclusions from that, and others focusing more heavily on the ambiguities in the data and the difficulties in making decisions in light of that ambiguity.

Constructing this unit took a sizable “leap of faith” on my part – I’m a behavioral ecologist who knew about as much about reformulated gasoline at the beginning of the semester as the students. Perhaps this was part of the problem, as the students clearly wished for more guidance. However, my lack of expertise also had a positive side. I was a partner in learning with my students rather than the “sage on the stage”. As such, they were forced to seek other resources to understand the issue. There were times when we experienced “aha!” moments together in the classroom – when we shared information with one another and suddenly we all understood the issue more thoroughly. There were also times when I could share their frustration at contradictions we encountered in information from various sources (or sometimes even from the same sources). In conclusion, I don’t feel that expertise in the subject area of the investigation is essential to a successful educational experience.

One of the objectives of this project was for students to get a sense of how scientists think, talk, and

act; and although there was no concrete data to support this, it could be detected in their voices as they presented their ozone/milkweed projects. Students who, at the beginning of the semester, freely and vocally admitted that they were not scientists, discussed their data with a level of critical analysis and self-confidence that one would be excited to see in Biology majors. Similar gains were seen in their writing. Each group was given the opportunity to rewrite their research proposal. Grades on the final draft were about two letter grades higher than would have been awarded on the initial drafts. Finally, students also provided anecdotal accounts of how proud they were when they could explain to their roommates what reformulated gasoline was and why it mattered.

In conclusion, I feel that the reformulated gasoline unit pushed students to critically analyze a contemporary environmental issue. In doing so, they had to learn a variety of scientific concepts and also how science is done. Most vividly, they wrestled with the role of uncertainty in science and how that uncertainty comes to play at the interface between science and public policy. This was a difficult and frustrating unit for many of the non-science majors. Yet student evaluations and my own impressions suggest that despite the frustration, many students found value in the experience. Most importantly, it allowed the students to work through the type of process they’ll need to undertake when they are trying to analyze an issue they read in the newspaper, but to do so with a variety of academic support structures in place. My recommendation for others interested in trying a similar approach in their courses would be to more intentionally develop the skills of critical analysis throughout the semester, using incrementally more difficult issues as stepping stones toward a final issue at the level of the reformulated gasoline issue investigated here.

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