

Integrating Policy into Science in the Classroom: Three Case Studies on the Atmosphere

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Abstract

Three case studies introduce undergraduate non-science students to policy components of air pollution, ozone depletion, and greenhouse warming. This article presents the versions of the case studies used during for a UCSD course entitled Introduction to Environmental Systems during Winter quarter 2003. Students work in groups of four or five to discuss the case studies, research background material, and reach a consensus about their own recommendations. Case studies are successful in engaging students in environmental policy issues, helping them master basic concepts, and creating enthusiasm for the course material.

1. Introduction

One challenge in Earth system science education involves engaging undergraduates so that they are able to apply the lessons that they learn formally in the classroom to environmental issues that affect them in their daily lives. This article describes a set of case studies used at the University of California San Diego for Environmental Systems 10: Introduction to Environmental Systems (ESYS 10).

ESYS 10 is intended as a broad one-quarter (10 week) introduction for UCSD's Environmental Systems (ESYS) program. The ESYS major encompasses both science and policy, allowing students to choose from specialized tracks in policy, biology, atmospheric chemistry, and Earth science. Students enroll in ESYS 10 for a number of reasons. Some are considering the ESYS major; some have a general interest in the environment; and others need to fulfill general education requirements.

The course uses a science-oriented text book, Introduction to Earth System Science [*Kump et al.*, 1999]. Four case studies serve as a means to introduce policy issues to the course and to make students think seriously about the core environmental issues covered in the course. Three of the case studies discussed here cover air quality, ozone depletion, and greenhouse warming. A fourth on marine biodiversity and overfishing is less structured and is not included here.

In addition to introducing policy concepts, the case studies are also designed to motivate independent research and to encourage students to feel a sense of "ownership" of environmental concepts. The case studies derive from the general concepts of problem-based learning [e.g. *Rhem*, 1998; *Duch*, 2001]. One goal of the class is to make sure that students understand the distinctions between air pollution, ozone depletion, and greenhouse warming. For example, I want students to grasp that CFCs, which destroy stratospheric ozone, are benign for us to breathe; that ground level ozone is a component of smog and a nasty pollutant; and that CO₂, the leading greenhouse gas, is a gas that we emit when we breathe, and not a pollutant that causes asthma.

This brief article describes the atmosphere-related case studies that were used in Winter quarter 2003. My own expertise is more oceanographic than atmospheric, and the case studies topics were selected to represent environmental policy issues that make headlines. Because environmental policy evolves continuously, most case studies will be updated before being used again. Section 2 describes each of the case studies and describes some of the traits that are common to all case studies and how they operate in my classroom. Section 3 evaluates the success of the experience. Anticipated future changes are described in Section 4, and the approach is summarized in Section 5.

2. Using the case studies

For all three of the atmospheric case studies in Winter 2003, students worked in groups of four or five. Students are assigned to groups in order to ensure diversity of gender, year of study, and major in each group. They normally remain in the same groups throughout the quarter, although enrollment adjustments require some adjustment of group assignments through the course of the quarter.

The first case study, entitled, "Should Alex Buy a Battery-Powered Car?" presents a group of four undergraduates (Alex, Baylor, Chris, and Dale), who debate whether Alex should take the plunge and buy a "zero emission vehicle" or ZEV. The case study was motivated by California's ZEV Program, which originally mandated that 10% of cars sold in 2003 should produce zero tailpipe emissions. The ZEV program originated in 1990 through the California Air Resources Board as an air-quality program, without concern for CO₂ emissions or greenhouse warming. (Over time, these objectives have shifted. Since the end of Winter quarter 2003, California's Air Resources Board has adjusted the objectives of the ZEV program to push for more fuel efficient gas-electric hybrids and eventually hydrogen fuel cell vehicles.) In the case study, students are asked to consider four possible stances: buying a ZEV as advocated by Alex, buying a hybrid gas-electric car (Baylor), pursuing public transportation and bicycling (Chris), or sticking to conventional vehicles (Dale).

In the second case study, entitled, "If I had a billion dollars to save the ozone layer", Pat, Riley, Tory, Sasha, and Vic debate ways to preserve stratospheric ozone. The discussion is initiated when Pat reaches for an asthma inhaler, and Riley protests that this will contribute to ozone destruction. By way of background, soon after the Montreal Protocol was signed, asthma inhaler manufacturers negotiated exemptions to the treaty, allowing them to continue to make use of ozone-destroying chlorofluorocarbons (CFCs) as medication propellants. Because asthma is life-threatening, many patients and doctors have been reluctant to switch to CFC-free medications, and the conversion to new inhalers has been slow. (When I survey my students who have asthma, most report that they have been using the same types of inhalers for 10 or 15 years, and therefore they assume that their inhalers are still CFC-propelled.) In the dialogue, Pat, Tory, and Sasha enumerate a range of additional problems that may lead to ozone destruction including methyl bromide, weak enforcement of the rules, and developing country emissions. Finally, Vic suggests that the Montreal Protocol is doing its job and that education (and staying out of the sun) may be the best strategies for managing stratospheric ozone depletion.

The final case study of the quarter, "Should the Senate Debate the Kyoto Protocol?", addresses greenhouse warming and the U.S. participation in international global warming negotiations. Students are asked to consider four possible standpoints on the Senate ratifying the Kyoto Protocol, as voiced by four summer interns at the Senate Committee on Foreign Relations. Izzy says that since global warming is a serious problem and the Kyoto Protocol is the only

international treaty to address the problem, the U.S. should participate. Jay counters that the Kyoto Protocol represents only a minor effort to reduce greenhouse gases in the atmosphere, and that the U.S. should advocate starting treaty negotiations anew. In contrast, Kendall suggests that the evidence for greenhouse warming is not clear enough to justify any strong measures. Finally, Lee argues that the debate over the Kyoto Protocol is about international politics rather than science, implying that the U.S. Senate's stance cannot be determined from scientific considerations alone. The topic plunges students into the complexities of international treaties and feels far removed from student's daily lives, which makes this a difficult case study.

The case studies are each presented as dialogues rather than narratives, because dialogues offer a succinct way to voice a number of opinions without the burden of narrative detail. The dialogues have a certain unrealistic quality: the undergraduate speakers are surprisingly well-informed about environmental topics, and they spew out whole paragraphs of fact and opinion without any interruption. Although this structure can feel a little clumsy, it works reasonably well in class. Dialogues can be read quickly by students, and the background information and opinions are grouped tightly, so that students can easily separate the multiple opinions that they are exploring.

Each case study requires two class sessions and a certain amount of outside work. Students receive the case study text to read prior to the first session. Even though the case study texts are short, students need to be assigned to read them before class. Allowing students time to read the case studies in class requires a surprisingly long time interval, since students read at different rates.

During the first session, they spend about 15 minutes discussing the basics of the case within their groups. I specifically ask them what additional information they will need in order to fully evaluate the case. The case studies normally present four view points, and each student chooses one viewpoint to research further and represent. At this point, I ask students to split into groups based on the viewpoint that they are representing---thus for the case study on ZEVs, all the Alex's joined together to consider what additional research will be needed before they argue the case for ZEVs to their classmates. Students are encouraged to find ways to split up research responsibilities so that they can explore the material more broadly. I circulate between the groups as they discuss to answer questions, prod discussion, and encourage them to consider alternate points of view.

Between the first and second sessions, students are expected to carry out independent research. I usually provide at least one factual hand out to provide some basic background information. The hand-outs often come from press offices. For the zero emission vehicle case study, the hand-outs included two fact sheets entitled "California's Zero Emission Vehicle Program" and "Zero Emission Vehicle Program Changes" [*California Air Resources Board*, 2001a, b]. as well as a New York Times article on the California policy [*Hakim*, 2002]. For the ozone depletion case study, the hand out is a Press Backgrounder on the Montreal Protocol [*United Nations Environment Program*, 2001]. For the Kyoto Protocol case study, students receive a Fact Sheet on the Kyoto Protocol [*White House Climate Change Task Force*, 1999]. In addition to these hand outs, the course web site identifies a wide range of web links that can serve as starting points for further research. Although many university faculty now worry that students neglect libraries in favor of doing all research electronically, for these current-events oriented case studies, the web provides a broad range of valuable resources. In addition to demanding student research, I also often invite a guest speaker to lecture the class in between the beginning and end of the case study. For example, Bill Brick, from the San Diego Air Pollution Control District, has proved to be a valuable resource to help place the ZEV case

study in context.

In the second class session, students return to their viewpoint groups to share the fruits of their research. Viewpoint groups are encouraged to determine what evidence they have that will most clearly support their stance. Finally students reform their original groups to attempt to reach a consensus on the case. We finish up with an overall class discussion to determine the major themes and the overall class opinions. In the ZEV case study, most students argue in favor of hybrid cars in the end. Likewise, most groups favor U.S. ratification of the Kyoto Protocol in the third case study. The ozone depletion case study has less well-defined outcomes, and the groups often reach differing opinions, allowing some useful class discussion.

One week after conclusion of case study, students hand in their own written summaries. I have normally treated the summaries as informal writing assignments, which I graded on a "check/check plus/check plus plus" grading scale. Summaries are normally one to three pages in length. I tell students that they need not be typed, but I usually point out that experience indicates that typed summaries seem to be more clearly thought out and therefore earn higher evaluations. I require that students include clear reference lists indicate the sources for their independent research, but I am not stringent about their methods for citing web sites.

Many instructors who use problem-based learning approaches such as mine ask that each discussion group submit a group report. In my experience, for relative short case studies such as these, group reports frustrate students, because they feel like their grades depend on their unreliable classmates. Problem-based learning instructors have developed a variety of techniques to help students motivate and work with each other. In my own class, however, rather than governing group dynamics, I have opted to demand that each student submit a full discussion of the case.

Group activities such as these case studies only work if students come to class regularly. Therefore attendance is mandatory in ESYS 10. Normally I take attendance as I circulate among the groups. This approach does not take time away from other class activities, but it leaves students aware that their attendance is being tracked. Ultimately attendance and participation are factored together to represent about 10% of the total course grade.

3. Evaluation of the experience

The overall success of the case studies used in ESYS 10 depends on two factors. First, do the students learn material more effectively than they would if they listened to longer lectures? Second, do students appreciate the case studies? For ESYS 10, both of these factors are difficult to evaluate, except in an anecdotal sense.

Overall, student reaction to ESYS 10 is positive. UCSD course evaluations are not designed to evaluate non-traditional teaching approaches. However, student survey responses are uniformly positive. Without exception, in the past two years, all of the ESYS 10 students (9 in 2002 and 17 in 2003) have indicated that they would recommend the course. Small enrollment courses tend to win positive teaching evaluations, but these numbers are particularly strong.

A comparative study at the University of Delaware showed little performance difference between students in "problem-based learning" sections and students in traditional lecture sections of a food service class. However, problem-based learners were much more positive about their course experience [Lieux, 2001]. Since UCSD does not offer multiple versions of ESYS 10 with and without case studies, we do not have a clear statistical means to compare learning from

case studies with learning in lectures. Exams normally include a range of short answer questions, that tend to test material from the textbook and lectures, and essay questions that tend to revisit material from the case studies. In general, students perform consistently well on essay questions, indicating that most have grasped the key concepts from the case studies. In contrast, performance on short answer questions appears to depend strongly on students willingness to read and review course material to prepare for the exams.

Case studies clearly stick with students long after the end of the term. Students who request letters of recommendation often stop by weeks or months later. As we chat about their plans, they sometimes bring up issues that evolve out of the case studies. ("My Mom just bought an SUV; I tried to persuade her to look at something more environmental.") In contrast details from the lectures and textbook reading have clearly slipped their minds.

In one notable exception to the generalization that students understand and retain material from case studies, in the Winter 2003 final exam, I asked students to comment on a newspaper columnist's comment that driving a sport utility vehicle (SUV) destroys the ozone layer. While top performers in the class easily identified this as a false statement, many others were taken in by this popular myth. Clearly in future years, the course will need to explore the distinctions between CO₂ and pollutant emissions and stratospheric ozone destruction more carefully.

4. Difficulties in the case study approach

Case study approaches to education present problems that are distinct from problems in lecture classes. This section summarizes some of the problems that have evolved in ESYS 10 and some of the problems anticipated in the future.

One first challenge involves convincing students to take up the viewpoint of one of the dialogue speakers. In 2002 versions of the dialogues, speakers were half women and half men. While the gender balance seemed valuable, the result was that male students specifically opted not to represent the viewpoints voiced by women. To avoid this problem, the dialogues were subsequently rewritten with gender ambiguous names. Names are grouped alphabetically (e.g. Alex, Baylor, Chris, Dana) to simplify blackboard discussion. Gender neutral names puzzle everyone, and students sometimes assume that the speakers are men or arbitrarily select genders for the speakers. However, the ambiguity in the names seems to serve the intended purpose of ensuring that students consider all opinions when choosing what viewpoint they would like to research and represent.

A second problem involves keeping students engaged in the small group discussion process throughout the quarter. As the term progresses, some groups are able to speed through their case study discussions so that they can spend class time socializing. For the socializing groups, class time would be more productive if the professor took over guiding a class-wide summary discussion of the case study. However, often when one group deteriorates into gossip, other groups continue to analyze the case productively. As the quarter progresses, it therefore seems particularly important to set clear guidelines and objectives for in-class discussion.

Would it be better to use case studies as basis for class-wide discussion rather than dividing students into groups? This might alleviate some of the difficulties with socializing groups, but overall students appear to feel more pressure to perform for a small group of peers than for a large class discussion. The use of groups seems to motivate the majority of the students to do independent work and to come to class prepared for discussion. Most students come supplied with notes or printouts indicating that they have spent time surfing their web to prepare for class

debate. In addition, small groups are considerably less intimidating than large classes, and students who rarely participate in full class discussion will happily contribute to small group discussion. This experience is borne out by the extensive literature on problem-based learning, which advocates small group activities as a means to engage students in the learning process.

Despite their engagement in group activities, in the first few case studies of the quarter, students sometimes have trouble remembering who is in their group, particularly because a week or more may pass between case study activities. During the first couple of case studies, students often need a refresher of the group participant lists. Students would probably identify more closely with their groups if they had to select team names, but I have so far not asked them to do that.

At UCSD, ESYS 10 has only been taught twice (in 2002 and 2003), both times to relatively small enrollments. However, the class is intended as a general education class, and ultimately should have an enrollment between 50 and 150 students. Larger enrollment will bring new challenges to the class. Teaching assistants can provide additional guidance for small group discussion. Since Scripps Institution of Oceanography graduate students have few opportunities to work as teaching assistants, I have sometimes recruited grad students to act as volunteer discussion facilitators. This necessitates some preparatory work; assistants must have a clear idea of the case study background, objectives, and discussion schedule in order to provide helpful advice to students.

Attendance would also be difficult to track in a class of 50 or 100 students. One strategy would be to stop monitoring attendance and assume that students would attend class anyway, particularly if they had interesting case studies to analyze and the threat of an eventual group-evaluation of their participation. A second strategy is to schedule weekly quizzes for the days when case study discussions will take place, so that students have an extra motivation to attend class on case study days. The literature on problem based learning provides a number of suggestions that may help in extending these case studies to large classes [*Dion, 1996; Shipman and Duch, 2001*].

5. Summary

At UCSD, a series of case studies accompanying Introduction to Environmental Systems (ESYS 10) ask students to apply the material that they learn in class to analyze specific environmental problems. This article has discussed the three case studies that focus on atmospheric air quality, stratospheric ozone depletion, and global warming. (A fourth, on overfishing, has a different feel, and is not included in this article.)

Case studies offer several benefits compared with simple lectures. Students do not fall asleep during small group discussion. They participate broadly in class discussion. And they seem to retain material that they have discussed during their case study analyses. The case studies presented here are sure to change in response to policy developments, scientific discoveries, and student comments, but the general case study structure is likely to continue in ESYS 10, provided it remains feasible as enrollment increases.

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