AC 2011-1367: TEACHING CLIMATE SCIENCE AND POLICY TO ENGINEERS

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Teaching Climate Science and Policy to Engineering Students

Abstract

A new course was developed to improve engineering students’ understanding of the earth science associated with global climate change, human interactions with climate, mitigation technologies and policies, and adaption strategies. The three-credit course, entitled *Global Climate Change: Science, Engineering, and Policy*, is highly quantitative and taught through an inquiry-based pedagogical approach. Every student is required to address questions about climate change phenomenon and investigate the historical data, related model predictions for future scenarios, and potential for mitigation and adaption. Students use multiple sources for energy and climate data (DOE, NASA, NOAA, etc.), simulation results from global climate models, and results from their own simulations utilizing climate models (EdGCM). Extensive use of MS Excel and Matlab are required for processing and analysis of the large data sets. The impacts of the course on the students were assessed with a combination of quantitative and qualitative approaches. Substantial quantitative gains were made in the students’ climate literacy, especially in knowledge areas. Students also showed gains in their self-reported feelings that they could solve a new problem or tackle a challenge, were good at interpreting charts and graphs and manipulating databases, and were interested in pursuing a career in science or engineering that would contribute to solving global climate problems. Qualitative assessment results indicated that students felt more confident in their ability to contribute to climate change mitigation through both their personal knowledge and professional career options.

Introduction

The scientific community now recognizes with a very high level of confidence that recent industrial and agricultural activities are having a profound impact on Earth’s climate.¹ The release of greenhouse gases into the atmosphere from these activities is causing a discernible warming and general instability of our planet’s climate. It is now time to help the broader community understand the science of climate change, its potential implications, and the actions required to mitigate and adapt to these changes. The knowledge, behaviors, and attitudes related to climate change can be broadly defined as “climate science literacy.” NOAA, AAAS, and others recently published a guide to climate literacy² that defines attributes of a climate-literate person. Achieving this type of literacy requires educational programming that will increase citizens’ knowledge about the biophysical environment and its associated problems, their awareness of how to help solve these problems, and the motivation to work toward their solution.³

The development of ideas and approaches to promote climate science literacy at Clarkson University parallels efforts to define, promote, and improve energy literacy.⁴⁵ Energy and climate literacy are integrally linked due to the predominant influence of CO₂ from fossil fuel combustion on our climate. Sound knowledge regarding energy use and conservation, increased efficiency of energy use, and alternative energy resources can all contribute towards both energy and climate literate individuals. Unfortunately, students generally do not understand energy science. Results from our survey of over 1200 New York State high school students in 2008 indicate low levels of energy-related knowledge, with less than 2% of the students scoring above
80%; and only 20% scoring above a typical passing grade of 65% while 75% of the students answered only 53% of the questions correctly. Affective and behavior scores are slightly better, suggesting that although students may recognize the energy problem, they generally lack the knowledge and capabilities to effectively contribute toward a solution. Intensive course work that combines a project-based approach with relevant problem-solving experiences does help to increase students’ energy literacy.

A review of literature and web resources in 2008 suggested that no course existed on climate change that was specifically tailored for engineering undergraduates. Climate change courses have been offered predominantly by science departments in American universities and, therefore, are not typically considered by engineering students. As the scientific debate has progressed beyond the existence of global climate change and has begun to focus on solutions, there is a tremendous opportunity for engineering students to contribute in significant ways to these discussions. Informed participation, however, requires these students to be educated, not just on the science of global climate change, but on energy and policy as well.

The pedagogical approaches proven to increase students’ environmental and energy literacy provide a framework for strengthening their climate science literacy. Project-based learning has been suggested as the most effective approach for teaching and learning science process skills and content. The curriculum is generally centered on a relevant real-life problem. Students learn and apply science content and skills in the formulation of their project solution. Using a project that is relevant to the students’ own lives encourages them to take ownership of their work and embrace the process. The technique improves student retention of science concepts, because they are interested and actively involved in what they are doing and they understand the relevance of the material to their own lives. According to Hurd, science instruction that is project/inquiry based, student-centered, and presented in a framework that relates to the “life world” of the student better prepares them as “productive students in today’s world,” effectively closing the gap between academic science and science for the citizen. Hurd further argues that, to fully modernize science, it should be connected to the “here and now,” to our technology-based society, and experienced by students within a personal and civic context.

NASA and other agencies offer a wealth of resource materials from which project-based climate change curricula can be developed for K-16 classrooms. NASA’s “MY NASA DATA” and Earth Science Education Catalogue provide lesson plans and access to data collected from NASA missions to enable inquiry and exploration of earth systems. The NASA Climate Change Eyes on the Earth website provides text and video details on climate change science and interactive opportunities to explore recent changes in our climate through the results of NASA data collection and modeling efforts. Other agencies (NOAA, NCAR, DOE, etc) also have rich databases and image files that are becoming valuable resources for classroom use. Numerous agencies have combined efforts to support the U.S. Global Climate Change Research Program.

The plethora of educational resources currently available can be overwhelming, especially for instructors who want to integrate and synthesize materials into a comprehensive project- or inquiry-based experience. Our project, which is funded through the NASA Global Climate Change Education (GCCE) program, seeks to improve climate science interest and literacy of a broad range of students, including undergraduate engineering students, by developing and
distributing inquiry-based climate change modules that integrate NASA data, models, and educational resources.

The basic premise of this project is that climate literacy education programs should address both content knowledge and problem solving skills. Effective instruction must incorporate scientifically-based knowledge and observations, not opinion-based beliefs. Equally important is the need to foster critical thinking, and decision-making skills so that students are better able to apply knowledge and skills in confronting and analyzing new, unfamiliar situations. Embedding climate change-related projects and classroom materials within a societal context will make the materials more relevant and interesting. Providing students with a holistic, inquiry-based climate change module, where student-centered activities are thematically tied to the solution of an overarching problem, may be a more effective learning strategy than a series of unrelated, lectures that passively feed information to students without requiring them to actively investigate and formulate their own analysis of the extent, causes and responses to our changing climate.

Description of Class

The primary objective of the undergraduate course described here is to facilitate learning to promote understanding and application of students’ knowledge related to the workings of the Earth’s climate system and the interactions between the atmosphere, ocean, and climate. A three-credit course, entitled *Global Climate Change: Science, Engineering, and Policy* was developed and taught in the Spring 2010 and 2011 semesters at Clarkson University. Because it was designed for engineering students, it is highly quantitative and taught through an inquiry-based pedagogical approach. Every student is required to address a critical question about a climate change phenomenon through their own investigation of the historical data, relevant model predictions for future scenarios, and potential for mitigation and adaption.

The course meets a variety of degree requirements among different majors and thus attracts a diverse student population. The prerequisites require Excel and Matlab skills with some statistics background strongly recommended. Given the short time period to establish the course and recruit students the first year (grant funds to offer this course were approved in October 2009), only seven students, including both graduate and undergraduate students, completed the course the first time it was offered. Twenty seven students, mostly upper class undergraduates, are enrolled in the second offering of the course. The S11 class includes 41% women, which is very high relative to both Clarkson’s engineering population and the entire school gender distribution. Students selecting the class represent a broad range of engineering disciplines (7 ME/AeroE, 2 EE, 3 CE, 5 EnvE), as well as engineering and management (4), and biology/environmental science (2). Seven of the students are working towards a minor in sustainable energy systems engineering, for which this is a choice between two environmental impacts courses. For the other undergraduate students, the course is counted as technical or professional elective and is categorized as a science, technology and society (STS) course to meet their general common education requirements.

The objectives are included in Table 1 with reference to the ABET Criterion 3 program outcomes. With the STS focus of this class as well as the in-depth analysis requirements, many of ABET’s program outcomes are addressed.
Table 1: Course objectives

<table>
<thead>
<tr>
<th>Course Objective</th>
<th>ABET*</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>To make students understand the essential principles of Earth’s climate system</td>
<td>a, c</td>
<td>HW, exams,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pre-post</td>
</tr>
<tr>
<td>To enable students to relate energy-use to climate change and identify</td>
<td>a, e, h, j</td>
<td>HW, exams,</td>
</tr>
<tr>
<td>opportunities for reducing these impacts</td>
<td></td>
<td>pre-post</td>
</tr>
<tr>
<td>To enable students to access appropriate databases and quantitatively assess</td>
<td>b, d, i, k</td>
<td>HW, project</td>
</tr>
<tr>
<td>the effects of climate change processes on earth systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>To enable students to understand the current global policies as related to climate</td>
<td>h, j</td>
<td>HW,</td>
</tr>
<tr>
<td>change</td>
<td></td>
<td>discussion</td>
</tr>
<tr>
<td>To prepare students to present their work professionally</td>
<td>g</td>
<td>project</td>
</tr>
</tbody>
</table>

*(a) an ability to apply knowledge of mathematics, science, and engineering; (b) an ability to design and conduct experiments, as well as to analyze and interpret data; (d) an ability to function on multidisciplinary teams; (e) an ability to identify, formulate, and solve engineering problems; (g) an ability to communicate effectively; (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context; (i) a recognition of the need for, and an ability to engage in life-long learning; (j) a knowledge of contemporary issues; (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The course outline (Table 2) illustrates a breadth of earth science, engineering and policy topics that are included. The progression of topics follows recommendations from climate literacy experts that suggest starting with recognizing and appreciating students’ preconceptions and misconceptions, and then proceeding to demonstrate that the earth’s climate is changing before moving into the scientific reasons, as a way to increase student engagement. Through these topics, we address several fundamental questions:

- How is the global Earth system changing?
- What are the primary causes of change in the Earth system?
- How does the Earth system respond to natural and human-induced changes? and,
- What are the consequences for human civilization?

In the absence of suitable textbooks, a variety of federal agency web-based resources are used to provide suitable readings to support this topic. These resources and suggested readings are available on our publically accessible web site for this class. The class is taught in a computer classroom, which provides an opportunity for short computer exercises approximately weekly. These workshop sessions enable the students to build skills necessary for their homework and project assignments.
Table 2. Topics included in Climate Change class for engineering students

**Unit 1: Historical evidence of climate changes**

- Climate cycles – historical patterns, recent trends
- Climate data acquisition (weather stations, tree rings, glaciers)
- Scientific interpretation of climate data (uncertainty, Climategate)
- Other indicators of climate change (northeast, polar ice cap)
- Introduction to NASA databases / Satellite missions

**Unit 2: Science of climate and climate change**

- Earth’s energy balance and the greenhouse effect
- Wavelengths, absorption by atmospheric species, radiation
- Greenhouse gases introduced
- Water cycle and its role in the greenhouse effect
- Carbon cycles, reservoirs
- Recent trends – GHGs
- Climate – global winds and circulation patterns
- Modeling and predicting global climate change
- Introduce global climate modeling

**Unit 3: Human Influences on Climate and Mitigating/Adapting to Change**

- Sources of GHGs
- Energy consumption patterns
- Estimating GHG emissions
- Mitigation measures – intro, IPCC scenarios
- Mitigation measures – policies (NYSCAP), geoengineering
- Guest lectures – Science and public policy, International polices

While the lectures for this class provide content breadth and ample opportunity for discussion, the homework and project assignments require the students to explore climate change topics in depth. It is through these assignments that we assess our expectations that the students learn to locate, use and interpret data describing our climate and how it is changing. Computer workshops and easy homework assignments during the initial weeks are used to help prepare students for their own independent inquiry-based investigations.

Homework problems are intended to provide students with a deeper understanding of the science of climate change (e.g., Box 1) and the skills necessary to access and interpret climate data (Box 2). Other homework assignments that focus on accessing and utilizing climate data are included on our class web page.22

**Box 1: Example Homework Assignment – Fundamental Basis for Global Warming Potentials:**

1) Calculate and plot the global warming potential (GWP) of CH₄ and N₂O as a function of time interval (ranging from 10-200 years). Use best estimates of radiative efficiency and lifetimes of the two species and for CO₂ (IPCC, 2007, Table 2.14). Assume an exponential decay of the concentrations as a function of time, with decay time constant being the time constant of decay. Assume that the radiative efficiency of all species is independent of time.

2) Contrast the GWPs of the above species with that of a long-lived species, such as CFC-13. Again plot the GWP of CFC-13 for a range of time intervals using best estimates of radiative efficiency and lifetimes of the CFC-13 from IPCC (2007).23 Make other assumptions as above.
**Box 2: Example Homework Assignment – data acquisition and interpretation.**

Access the NASA website “live action server” [http://mynasadata.larc.nasa.gov/las/servlets/dataset](http://mynasadata.larc.nasa.gov/las/servlets/dataset)

Evaluate snow cover (cryosphere) for the region around Potsdam NY (45°N 75°W) for the period January 1994 through June 2008

Use the time series ASCII file created from My NASA Data to quantify and graphically address the following questions (You can open this file into Excel for your analysis or use Matlab to “mine” these data):

- What months of the year did we consistently have significant snow coverage (> 50%)?
- For each winter month (DJF), plot the snow cover as a time series.
- Determine the mean and standard deviation of the snow cover in Winter (DJF) and Spring (MAM) quarters considering the available data (1994-2008).

**Discussion:**

- Describe the procedure you used to access, sort and evaluate these data. Was this an effective approach or could you do better with a more automated approach (Excel macro or Matlab program)?
- Discuss the trends in each of the questions above. Can you identify any trends in the above data that could be related to climate change?
- Describe how these data were collected (satellite mission, type of sensor, etc.)
- What is the spatial resolution of the data? How does that affect the quality of your answers above?
- What other sources for this same data could you use to supplement the NASA satellite data? Where would these data come from? How would you access them?

The semester project was developed from the NASA strategic science plan for research on climate change[^24] that defines several fundamental broad questions related to how and why our Earth’s systems are changing. Addressing these questions requires an understanding of the interactions among natural phenomena and anthropogenic influences as shown in Fig. 1. The goal of the semester project is to answer a research question related to climate change through the use of a variety of databases (quantitative and/or pictorial) and quantitative tools. The project requires the use of real-world data from NASA and other federal agencies, critical analysis of the causes and consequences of climate change, and (possibly) personal decisions necessary for mitigating or adapting to these changes. Students are required to select a research question, write a proposal for addressing the question, collect data, complete the proposed analysis, and report results in both written and oral presentation formats.

The students used multiple sources for energy and climate data (DOE, NASA, NOAA etc.), simulation results from global climate models, and results from running their own climate models (EdGCM) to answer their respective questions. Extensive use of MS Excel and Matlab are required for handling and analysis of the large data sets. Some examples of projects completed in the Spring 2010 semester include:

- What is the response of the global radiation balance from increased atmospheric CO₂?
- In important corn production areas (42°N in the U.S.), is the length of the growing season changing because of climate change?
- What is the correlation between cloud coverage and precipitation? How would this influence geoengineering efforts?
- What are the effects of global climate change on quantity and equity of rainfall distribution?
Figure 1. Cause and effect relationships in anthropogenic and natural systems that affect climate and social systems. (adapted from)

Figure 2 illustrates the results of one student’s project. This student took a classic graphic depicting the global average radiative fluxes that control heat transfer to the earth and determined the fluxes for a more localized region. The project was successful because it showed the possible estimates that could be made with climate data available through federal agencies and the variability between global average fluxes and localized values. Throughout the class, the benefits and limitations of aggregating and disaggregating data in global versus regional changes is stressed and very apparent from our data interpretation. The students become very aware that although climate change is most often presented in terms of global phenomena, the contributions and consequences must be interpreted on a much more regional scale.

Assessment

The assessment plan focuses on measuring two fundamental aspects: the change in students’ content knowledge, skills, affect, and behaviors related to global climate change, as well as the effectiveness of new educational modules. We use a mixed-methods approach that includes
quantitative surveys administered pre- and post-course participation and qualitative focus group discussions at the end of the course. Educational content, affect, and behavioral competency surveys, containing a combination of multiple-choice (content based) and Likert-type scale (affective, behavioral) items were developed using established principles and methodologies from the sociological and educational sciences. Key quantitative assessment tools include:

- **Climate Literacy Questionnaire** (knowledge, affective, behavioral assessment): Based on the criteria outlined in the *Climate Literacy* report, a new survey was developed following established techniques to assess content mastery, affective, and behavioral changes toward global climate change and climate change science (Table 3).

- **Competency Survey**: An *Engineering Self-Efficacy Scale*, which contains 15 Likert-type statements, was developed and used as part of a previous NSF-funded gender equity program at Clarkson University. It was adapted and used in this project to evaluate participants’ feelings of personal competency relative to NASA education and career goals and scientific/technical careers related to climate change.

Surveys were administered at the beginning and end of the semester for summative purposes. Statistical applications, including inferential statistics such as paired sample t-test, have been used to measure pre/post changes in student responses. Analyses were conducted with Microsoft Excel and the *Statistical Package for Social Sciences* (SPSS) Statistics Version 17.

The Climate Literacy assessment instrument was created from several other existing instruments, with the goal of selecting and developing questions that would align the instrument with the content of the *Climate Literacy* report. The instrument measures all three components of literacy: knowledge, affect and behavior (Table 3). A first version of the survey was piloted in the Spring 2010 class, and was also administered to 105 students at Clarkson University and 360 incoming students at SUNY-Environmental Science and Forestry for reliability testing and item analysis. Based on the pilot analysis, some questions were eliminated and a shorter survey was created that is being used with the college students currently enrolled in our climate change course (S11). The survey is administered through Zoomerang and takes approximately 20 minutes to complete.

Results from the 2010 pilot surveys were used to test the instrument’s reliability and validity. Values for Cronbach’s alpha internal consistency reliability coefficient, α, for the three subscales were knowledge=0.71, behavior=0.74, and affect=0.88. All of these values are greater than minimum acceptable limits - at least 0.7 for a set of items in social science scales and as low as 0.60 for educational assessment scales. Standard Error of Measurement (SEM) values for the three subscales ranged from 2.1% to 4.0%, well below the maximum recommended limit of 7.5% for instruments comprised of multiple subscales. The instrument’s validation was supported by administering the pilot to a “known group” of subjects who were expected to be climate literate. The known group consisted of 10 public middle and high school teachers attending a climate change curriculum development workshop at Clarkson University, which was also as part of the NASA GCCE grant. The teachers scored significantly higher than the college students that comprised the pilot group on knowledge (p<<0.001) and behavior (p=0.0002) subscales, with no appreciable difference between the two groups on the affective subscale.
Table 3. Example questions included on the Climate Literacy Survey aligned with climate literacy principles and designated according to attribute: knowledge (K), affect (A), or behavior (B).

<table>
<thead>
<tr>
<th>Principle 1. The Sun is the primary source of energy for Earth’s climate system.</th>
</tr>
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<tbody>
<tr>
<td>Earth’s atmosphere is warmer than it would be without a greenhouse gas effect. Which form of energy is absorbed by the atmosphere and mainly causes this temperature increase? (K)</td>
</tr>
<tr>
<td>A. Radio</td>
</tr>
<tr>
<td>B. Infrared</td>
</tr>
<tr>
<td>C. Visible</td>
</tr>
<tr>
<td>D. Ultraviolet</td>
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<tr>
<td>E. X-ray</td>
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<table>
<thead>
<tr>
<th>Principle 2. Climate is regulated by complex interactions among components of the Earth system.</th>
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<tbody>
<tr>
<td>The difference between weather and climate is: (K)</td>
</tr>
<tr>
<td>A. Weather is a day-to-day event while climate is a consistent pattern over a year or longer.</td>
</tr>
<tr>
<td>B. Weather is local, but climate is global.</td>
</tr>
<tr>
<td>C. Weather is predictable but climate is not.</td>
</tr>
<tr>
<td>D. Weather includes more variables like moisture and wind while climate just focuses on temperature and precipitation.</td>
</tr>
<tr>
<td>E. I don’t know.</td>
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</table>

<table>
<thead>
<tr>
<th>How convinced are you that global warming is happening? (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Completely convinced</td>
</tr>
<tr>
<td>B. Mostly convinced</td>
</tr>
<tr>
<td>C. Not so convinced</td>
</tr>
<tr>
<td>D. Not at all convinced</td>
</tr>
<tr>
<td>E. I don’t know</td>
</tr>
</tbody>
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<tr>
<th>Principle 3. Life on Earth depends on, is shaped by, and affects climate.</th>
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<tbody>
<tr>
<td>Which of the following is a cause of global climate change? (K)</td>
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<tr>
<td>Burning fossil fuels</td>
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<tr>
<td>Nuclear power generation</td>
</tr>
<tr>
<td>The ozone hole in the upper atmosphere</td>
</tr>
<tr>
<td>Livestock production</td>
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<tr>
<td>Dumping trash into our oceans</td>
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<tr>
<td>Waste rotting in our landfills</td>
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<tr>
<td>Radioactive waste from nuclear power plants</td>
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<tr>
<td>Agricultural use of chemical fertilizers</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Which of the following actions will help slow down or reduce global climate change? (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building more nuclear power stations instead of coal power stations</td>
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<tr>
<td>Planting more trees in the world</td>
</tr>
<tr>
<td>Making more of our electricity from renewable energy resources</td>
</tr>
<tr>
<td>Recycling more</td>
</tr>
<tr>
<td>Not wasting electricity</td>
</tr>
<tr>
<td>Fertilizing the oceans to make algae grow</td>
</tr>
<tr>
<td>Reducing air pollution from toxic chemicals</td>
</tr>
<tr>
<td>Changing lifestyles to reduce consumption</td>
</tr>
<tr>
<td>Limiting the use of aerosol spray cans</td>
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<table>
<thead>
<tr>
<th>Principle 5. Our understanding of the climate system is improved through observations, theoretical studies, and modeling.</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do you think information on global climate change is collected? (choose all that apply) (K)</td>
</tr>
<tr>
<td>ground measurements</td>
</tr>
<tr>
<td>cell phones</td>
</tr>
<tr>
<td>satellites</td>
</tr>
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</table>

**Principle 4.** Climate varies over space and time through both natural and manmade processes.

**Principle 6.** Human activities are impacting the climate system.

If human civilization had never developed on Earth, would there be a greenhouse effect? (K)

- A. Yes, the greenhouse effect is caused by naturally occurring gases in the atmosphere.
- B. Yes, the greenhouse effect is caused by plants giving off gases during photosynthesis.
- C. No, the greenhouse effect is caused by humans burning fossil fuels and releasing pollutants.
- D. No, the greenhouse effect is caused by humans depleting ozone in the atmosphere.
- E. No, there is no conclusive evidence that the greenhouse effect exists.

If global warming is happening, do you think it is caused mostly by human activities, or caused mostly by natural changes in the environment? (A)

- A. Mostly by human activities
- B. Mostly by changes in the natural environment
- C. Caused equally by human activities and the natural environment
- D. Global warming is not happening
- E. I don’t know

**Principle 7.** Climate change will have consequences for the earth system and human lives.

Which of the following are real and possible consequences of global climate change? (K)

- More people will get skin cancer.
- There will be food shortages in many parts of the world.
- There will be more deserts in the world.
- Island nations will disappear due to sea level rise.
- There will be more and larger storms in many parts of the world.
- The extinction rates of Earth’s plant and animal species will increase.

Please indicate to what extent you agree with each of the following statements (A) (Strongly agree ↔ Strongly disagree)

- I believe I can take actions that will help reduce global warming.
- The actions of a single person won’t make any difference in reducing global warming.
- The actions of a single country like the United States won’t make any difference in reducing global warming.

How do you feel about each of the following possible ways for the federal or state governments to reduce global warming (Strongly favor ↔ Strongly oppose) (A)

- Requiring automakers to increase the fuel efficiency of cars, trucks, and SUVs to 35 miles per gallon, even if it meant a new car would cost up to $500 more to buy.
- Increasing taxes on gasoline so people either drive less or buy cars that use less gas.

How often you currently do each of the activities described, when the situation arises (Almost always ↔ hardly ever) (B)

- Walk or bike to go short distances, instead of driving or asking for a ride in the car
- Buy compact fluorescent light bulbs instead of incandescent bulbs
- Turn off your computer when you are done with it
- Turn off the lights when you leave the room
- Turn down the thermostat or air conditioner to save energy

The pilot results also provided a means for selecting a suitable subset of questions to retain for a shorter, more practical instrument. Using a combination of statistical procedures and qualitative analysis, each item was evaluated for its individual value as well as its consistency with the rest of the subscale and, ultimately, its contribution to the instrument’s overall content objectives. Statistical procedures primarily involved assessing each item’s contribution to the overall
subscale reliability (Cronbach’s α), and the discrimination index, which correlates each respondent’s score on an individual item with his/her overall subscale score. The culminating test for the group of retained questions as a whole was to ensure that the internal consistency reliability and standard error values were reasonable, and all of the major objectives outlined in the Climate Literacy report were still addressed. In all, 22 knowledge (with three multi-part questions), 16 affective, and 12 behavioral items were retained for the current version of the survey. The Cronbach’s α values for the set of retained items in each subscale are 0.67, 0.69, and 0.86, for knowledge, affect, and behavior, respectively, with the average discrimination index ranging from 0.22 (knowledge) to 0.49 (affect).

The assessment of changes in the pre-post survey for the pilot class offered in the Spring 2010 semester showed that gains were made in the students’ climate literacy (Table 4). The most statistically significant gains were in the knowledge aspects. The number of students tested was too low to formulate definitive conclusions. However, results of the Spring 2011 class will be more informative.

<table>
<thead>
<tr>
<th>Climate Literacy Component</th>
<th>Score (%)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>gain</td>
<td>p-Value*</td>
</tr>
<tr>
<td>Knowledge</td>
<td>65.0</td>
<td>77.6</td>
<td>12.6</td>
<td>0.001</td>
</tr>
<tr>
<td>Affect</td>
<td>78.4</td>
<td>85.2</td>
<td>6.7</td>
<td>0.143</td>
</tr>
<tr>
<td>Behavior</td>
<td>64.9</td>
<td>74.7</td>
<td>9.8</td>
<td>0.111</td>
</tr>
</tbody>
</table>

* matched t-test, n=7

Despite the small class size, some initial observations can be made regarding specific student gains in climate literacy. For example, students felt more strongly after taking the course that they would consider a presidential candidate’s position on global warming when choosing about for whom to vote, and they considered global warming to be a more serious threat to the earth’s plants and animals after taking the course. Cognitive gains were significant in a few key areas:

- More students understood the nature of the earth system’s energy balance and its relationship to global climate change;
- Students experienced a 100% increase in their understanding of the longevity of CO2 in the atmosphere;
- Students better understood the causes of global climate change, including the fact that nuclear power plants and toxic industrial emissions do not contribute to global warming; and
- More students understood that planting trees will help mitigate global warming.

The impacts of the course on the students were also more broadly assessed with engineering self-efficacy surveys and qualitative focus group discussions at the end of the course. Students showed gains in their self-reported feelings that they could solve a new problem or tackle a challenge, were good at interpreting charts and graphs and manipulating databases, and were interested in pursuing a career in science or engineering that would contribute to solving the global climate problems. Qualitative assessment results indicated that students felt more confident in their ability to contribute to climate change mitigation through both their personal knowledge and professional career options.
In general, we’ve found that some of our engineering students are interested in applying their skills towards mitigating or adapting to changes in our earth’s climate. Providing a class that helps them to link the science content to their engineering skills has helped to increase their engagement and appreciation for their role in addressing climate change. Class materials are available for use in other Universities and will continue to be updated as our class evolves.

References


Clarkson University, Global Climate Change: Science, Engineering and Policy A new class primarily for engineering students http://www.clarkson.edu/highschool/Climate_Change_Education/college_level_class.html


NASA Science Strategic Plan http://nasascience.nasa.gov/about-us/science-strategy/Science_Plan_07.pdf (Section 2.2.1; Chapter 4) <accessed January 2010>.


