Matthew Kuperus Heun

Campus Carbon Neutrality as an Interdisciplinary Pedagogical Tool

Matthew Kuperus Heun, David Warners, and Henry E. DeVries II

Climate change caused by global warming provided a compelling context to engage engineering and ecology students in a semester-long, interdisciplinary, service-learning activity. We addressed three levels of inquiry throughout the semester: global, institutional, and personal. At the global level of inquiry, traditional classroom lectures and discussions reviewed climate change science and the role of energy systems in climate change policy. At the institutional level of inquiry, students were collectively asked the simple question, "What would it take to make our campus carbon neutral?" The students' response, a detailed final report entitled "The Calvin College Carbon Neutrality Project," was presented in a public seminar with several administration members in attendance. At the personal level of inquiry, students (and faculty) participated in a Carbon Emissions Trading Simulation. Participants were allocated carbon credits for personal carbon-emitting behaviors that were bought and sold in a simulated market. Our efforts benefitted considerably from the involvement of the Vice President for Administration, Finance, and Information Technology, who acted as the customer for the Calvin College Carbon Neutrality project and as the government in the Carbon Emissions Trading Simulation. We realized numerous pedagogical, social, and institutional benefits from this initiative. We believe that interdisciplinary, service-learning experiences as described here provide invaluable tools for preparing today's students to meaningfully address the significant global, institutional, and personal environmental challenges that lie ahead.

Climate change due to global warming is becoming increasingly important to our world, educational and business institutions, and individuals. Recent reports by the United Nations Intergovernmental Panel on Climate Change[1] indicate that the ever-increasing concentration of greenhouse gasses (GHGs) in earth's atmosphere[2] prevents heat from escaping and warms the planet. Climate change due to global warming is an issue with scientific, environmental, economic, development, and political dimensions.[3] Because the major contributing greenhouse gas, carbon dioxide (CO_2), is emitted by fossil fuel combustion when creating electrical and thermal energy for daily living, there are direct links between global warming and the activities of individuals, institu-

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Article

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tions, and nations. (Even if readers consider anthropogenically-caused climate change to be dubious, taking precautionary actions to temper its significant outcomes is the most prudent response.[4])

Net (i.e., emissions less sequestration) CO_2 emissions (or CO_2 equivalent emissions) are fast becoming a proxy for the overall environmental impact of an individual or an organization. Sequestration may be accomplished by planting additional trees or by purchasing emission credits associated with GHG emission reduction or sequestration projects elsewhere. An organization is said to be "carbon neutral" when its CO_2 emissions are equal to its CO_2 sequestration capacity.

Although global warming has become contested territory in public discourse, we believe that the biblical mandate to be stewards of creation provides Christians with the responsibility to seriously consider the scientific evidence and alter behavior to better care for the natural world.[5] An understanding of the deep love our Creator has for the entire cosmos (John 3:16), as well as the mutual interdependency of human and nonhuman flourishing, lead us to believe that the creation has intrinsic, not just instrumental value.

By assigning the Calvin College Carbon Neutrality (CCCN) project and by participating in the Carbon Emissions Trading Simulation (CETS), we sought to engage students in a relevant topic and to cultivate their creation care ethic by developing a deeper understanding of how institutional and personal behaviors contribute to global warming. We did this by asking the simple question, "*What would it take to make our campus carbon neutral?*" (While CO_2 is not the only greenhouse gas, our efforts focused on CO_2 because it is the major contributing greenhouse gas of our college campus.) This was a grass-roots, bottom-up effort by a pair of individual faculty members, not a top-down directive from college administration. As such, it is consistent with a campus culture that encourages faith-based academic service-learning using the institution itself as an educational tool.

Goals

Teaching climate change in a traditional lecture-style classroom format can accomplish several educational objectives. However, the approach we chose allowed us to engage educational objectives unattainable in a traditional classroom. The outcomes we hoped for were beyond academic; we wanted this project to cause our students to see the world, to understand their place within the world, and to think about their future with a more informed mindfulness. We wanted our students to understand this issue in a participatory manner, most importantly because global climate change is a real-life, real-time issue in which they are actual participants. To accomplish these objectives we designed the learning to proceed in an experiential fashion—we wanted our students to familiarize themselves with the concepts and terminology of climate change, learn to appreciate the complexity of this topic, and begin to appreciate the momentous challenge of living carbon-neutral lives.

Our goal was to accomplish these objectives at three levels of inquiry—personal, institutional and global. A significant obstacle for engaging individuals in a topic as broad as climate change

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Henry E. DeVries II

is to convict them of their complicity. Focusing our students to think about carbon neutrality on their own campus and in their own lives brings the global issue much closer to home. To do this we had them participate in a Carbon Emissions Trading Simulation (CETS, see p. 92). In recognition of the multidisciplinary nature of climate change, a final goal of this effort was to require students to work in groups of mixed disciplines. For climate change to be meaningfully addressed, a wide variety of interest groups and expertise must come together. The best way for our students to understand the importance and difficulty of such a venture is to provide them with an arena in which they themselves can experience the dynamics, difficulties, and rewards associated with interdisciplinary collaboration.

Project Structure

Achieving carbon neutrality requires assessment of both CO_2 emissions and CO_2 sequestration as a first step. Carbon neutrality provides a rich environment for interdisciplinary learning where, in our situation, engineers could assess emissions and biologists could assess sequestration. To achieve this interdisciplinary learning environment, two upper-level classes, one an engineering class and the other a plant ecology class, participated in the project.

In recent years, the fourth-year Design of Thermal Systems class has utilized a dual-track teaching approach. The first track contains traditional engineering thermodynamics and system design material focused on electricity production from fossil fuel sources. The second track utilizes academically based service-learning group projects covering renewable energy and energy efficiency topics. Each of the past projects[6] for this course had been integrated into the Calvin Environmental Assessment Program (CEAP), a loosely organized faculty group committed to implementing service-learning projects in science classes. The carbon neutrality project was a natural outgrowth of previous engineering class projects and fit well within CEAP.

Investigations in Plant Ecology is a research-focused class for undergraduate junior- and senior-level biology majors. This course is generally taught in the style of a graduate-level seminar, where students lead discussions on papers from the primary literature and also carry out their own scientific experiments. Since the approach of this biology course has always been student led, it fit well into our overall objectives for the carbon neutrality effort.

Semester Schedule

Schedules were arranged so that the two classes overlapped for one hour each week. For these joint sessions, all of the students, both faculty, and the Vice President for Administration, Finance, and Information Technology met together. During the first of these joint meetings, students identified topical groups needed to accomplish this project, after which we assigned students into groups based upon student preference, past academic performance, and background experiences. Each group was composed of at least one engineering student and at least one biology student. As added motivation, students were scheduled to present their findings at a public seminar at the end of the semester.

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Administration Involvement

Administrative support was essential for the success of the CCCN project as students navigated the political and financial landscape of the college. The Vice President for Administration, Finance, and Information Technology (Henry DeVries) was an eager participant in the CCCN project. He provided feedback during student presentations and became an information resource for participants. At the vice president's direction, members of the college's physical plant led student tours of facilities, answered questions about operations at the college, and provided current and historical data to the students. Several of the administrative and physical plant personnel who supported CCCN became interested in the project and attended student briefings.

Summary of Pedagogical Approach

We utilized three classroom activities to address the three levels of inquiry (Figure 1). Arrows point away from classroom activities toward project elements addressed by those activities. Traditional lectures allowed us to focus on global issues {A}; a Calvin College Carbon Neutrality (CCCN) project allowed us to address institutional issues primarily {C} and global issues secondarily {B}; a Carbon Emissions Trading Simulation (CETS) allowed us to address the personal level of inquiry primarily {E} and the global level secondarily {D}. In addition, the CCCN project and the CETS informed each other {F} and {G}. Figure 1 provides the framework for the remainder of this paper.

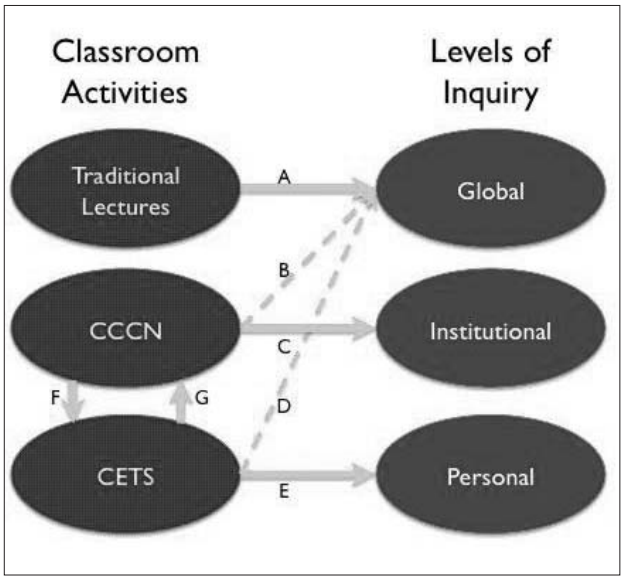

Figure 1. Interactions among project elements. Letters in braces {} in the text refer to labeled arrows on this figure. For example, {A} refers to the arrow from "Traditional Lectures" to "Global."

Traditional Lectures {A}

Traditional lectures in the engineering class focus on advanced heat transfer, thermodynamics, and fluid flow topics. Availability (exergy), combustion, optimization, and economic analysis techniques are employed to evaluate and design a natural-gas–fired co-generation power plant that makes two useful products: electricity and steam. Although natural-gas combustion emits less CO_2 than coal combustion per kW-hr of electricity produced, such plants do contribute to global warming and thus to climate change. And, it is imperative for students to have the tools to assess the contribution of these plants to climate change.

For the traditional biology class time, students began the semester with a brainstorming session, in which they raised questions about global climate change. The questions were then arranged into topical groups (e.g., scientific evidence, climate models, predicted outcomes, human rights, etc.) from which we designed a semester-long discussion schedule.[7] Students took turns identifying specific topical articles for the class to read and led discussions based on the readings they had selected. In this way, all the questions students had identified at the outset of the semester were researched and discussed by the end of the semester.

Calvin College Carbon Neutrality (CCCN) Project {B}, {C}, {F}

Group Assignment Process

After an introductory lecture, students defined an initial list of groups necessary for the project to be successful and identified the group in which they would like to work. The groups were required to be aligned with our college's Statement on Sustainability,[8] a document that outlines thirteen categories for campus sustainability. The students formed five groups covering the following topics:

- Energy Use and Purchase
- Land Use and Waste Water Management
- Recycling and Solid Waste Management
- Construction and Renovation
- Transportation

Professors assigned students to these groups using criteria described in "Semester Schedule" (p. 87).

Group Weekly Meeting

Each group began their work by generating an estimate of how much their particular category contributed to the overall carbon emissions of the campus. After the initial oral progress reports, it was clear that some activities contributed far more to the campus carbon footprint than others. Because emissions contributed by Land Use/Waste Water Management and Recycling/Solid Waste Management were so small, these two groups were reconstituted into a Finance group midway through the semester.

During the semester, groups shifted from assessing the amount of emissions generated by their category to brainstorming solutions for decreasing these emissions. The Finance group served as a filtering reality check on the proposed solutions and selected projects that were both feasible and marketable to be included in the final report. Once these had been selected, the Finance group generated a financial plan, taking into account inflation, the time-value of money, and the college's total budget.

Group Reporting

Weekly combined class meetings provided students with structured time to work together in their groups, with faculty available for guidance. Every third week was reserved for oral progress reports. These proved to be critical times of trying out ideas, coordinating reporting formats among groups, identifying areas that needed further work, and honing public speaking skills. The Vice President for Administration, Finance, and Information Technology provided key input at these times, input that provided a level of project authenticity for the students. Because the final report was to be formally submitted to this administrator, his consistent input gave assurance that the project would provide meaningful information for future college decision making.

After the first oral progress report, students identified a need to better coordinate the work of the various groups, so they formed an executive committee composed of one member from each of the study groups. This executive committee met at least once a week over the duration of the semester and was integral to synthesizing the individual group efforts into a cohesive, integrated product at the end of the semester.

The five individuals (three engineering students and two biology students) from the executive committee produced a presentation for the public seminar. In addition to over one hundred students and professors, the end-of-semester seminar was attended by the college president, the college architect, sustainability directors from two other local colleges, and the sustainability coordinator for the city of Grand Rapids. The students received high praise, including a personal letter of thanks from the mayor of Grand Rapids.

Results

There were two significant results from the CCCN project, the first-ever assessment of our campus carbon footprint and a carbon neutrality action plan.

Campus Carbon Footprint

In assessing the carbon footprint of the college, students were assisted by Physical Plant personnel who provided access to historical utility (both electricity and natural gas) and gasoline purchase records. These purchases were then converted to equivalent CO_2 emissions based on the mix of source fuels in our area (nuclear vs. coal, for example) and their conversion efficiency.

There was substantial debate about whether to count student and professor commuter traffic as contributing to college CO_2 emissions. Some argued that the college does not pay for commuters' fuel, so the college should not be responsible for commuters' emissions. Others held that the college should be accountable for commuters' emissions, because it can influence commuting patterns by providing incentives and disincentives that would reduce commuting emissions. Example actions include subsidizing bus riding, rewarding bike riding, providing financial benefits for living closer to campus, and causing commuters to pay the true cost for building and maintaining parking lots. In the end, students did include commuter emissions in the college's carbon footprint.

The students' analysis of carbon emissions revealed that the biggest contributors are building energy use and transportation (Figure 2). Electricity demand causes more emissions than space heating. And, commuting composes the bulk of our transportation emissions. The "other" category is a minor contributor and includes land maintenance, construction, and waste.

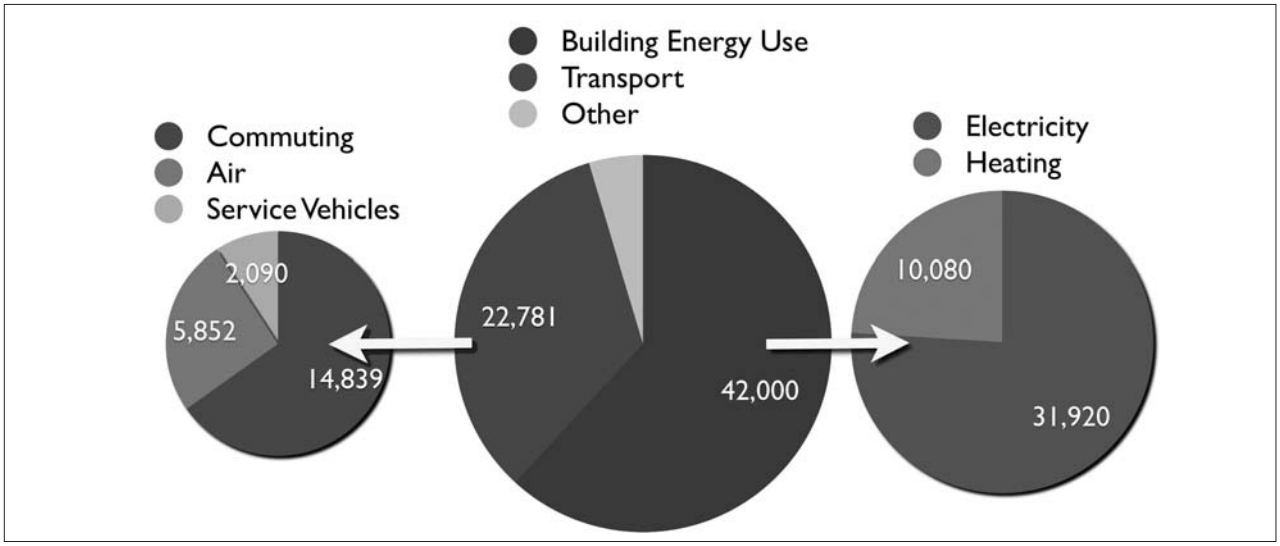

Figure 2. Campus CO_2 emissions (in metric tons of CO_2 emitted per year).

In terms of sequestration, the CCCN project students were assisted greatly by a previous study[9] of the carbon sequestration potential of land owned by the institution. Students refined the results of the previous study and reported the sequestration potential of various vegetation types for our campus (Figure 3).

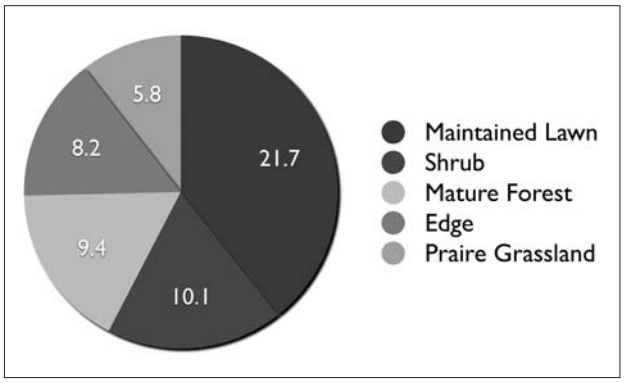

Figure 3. Campus sequestration (in metric tons of CO_2 sequestered per year).

A comparison of the carbon emissions and sequestration for our campus, based on the students' data, was alarming (Figure 4). This evaluation made it clear that increasing sequestration on campus is not a reasonable means of achieving carbon neutrality. Doing so would require a 1235-fold increase in sequestration to neutralize campus

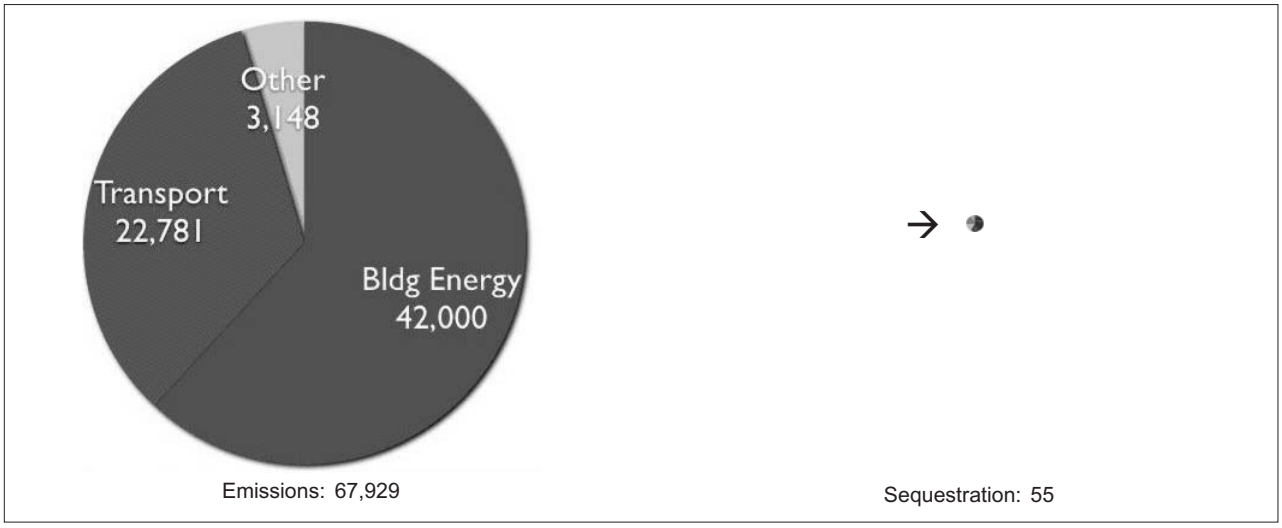

Figure 4. Comparison of CO_2 emissions and sequestration (in metric tons of CO_2/year). Area of pie charts is in relative proportion to CO_2 emissions and sequestration. Sequestration indicated by arrow.

emissions—not remotely feasible in today's world. Thus, the best option for achieving carbon neutrality is reducing CO_2 emissions.

Carbon Neutrality Action Plan

Guided by the results from the campus carbon footprint, students began work on a carbon neutrality plan. The first step was brainstorming a list of options for reducing CO_2 emissions. Table 1 shows a selection of the reduction options developed by the students.

The students developed an evaluation metric for the options: the ratio of dollars spent per emissions reduction. So, for example, a monthly electric vehicle gift to students has a very high ratio of cost to emissions reduction. Ideas at the top of the table are very cost-ineffective ways to reduce CO_2 emissions. In the second row from the bottom, reducing winter building temperatures is economically beneficial for the college due to reduced natural gas purchases. And, the bottom row indicates that enforcing daily "pay as you park" fees with higher parking rates will both provide a disincentive for driving to campus and be revenue-positive for the college.

The students proposed a phased plan wherein the college would slowly move up the table. The first step would be to generate revenue from the temperature drop and parking fees in the short term (10 years or so). These revenues would be saved in a carbon neutrality fund. After a decade or so, the college would purchase land in a suitable location and install renewable energy production machines (wind turbines) to further reduce campus CO_2 emissions. The fund balance would continue to grow over time, because cost savings from electricity that the college would no longer purchase would be reinvested in the fund. In future years, additional turbines could be purchased. The students developed cash flow and carbon emissions diagrams for their plan.

How CCCN Informed CETS {F}

Information gathered for CCCN about CO_2 emission and sequestration rates was essential for determining the campus carbon footprint. We required that the students use the emissions rates to move the Carbon Emissions Trading Simulation (p. 92) accounting system from an activity basis to a mass basis {F}. This assignment ensured that the students utilized (again) the information that they were gathering for the CCCN project.

Table 1. Table of a Selection of the CO_2 Emissions Reduction Options Studied

	Carbon Reduction [MTCe/year]	Cost [$]	Ratio [$/(MTCe/year)]
Monthly EV gift for students	1.25	$240,000.00	$17,454.55
Campus safety in EVs	0.96	$80,000.00	$7,575.76
College-owned bikes	1.258	$3,000.00	$2,385.38
Adding Lake Drive bike lane and path	14.93	$21,000.00	$1,407.00
Full Rapid subsidization	264	$94,492.00	$358.53
Renewable energy production	5548	$820,000.00	$76.00
Green energy purchase*	-19571	$724,000.00	$37.00
Carbon offset purchase	∞		$9.00
Temperature drop	3555	($172,000.00)	($48.00)
Daily commuter fees with increased rates	678	($83,000.00)	($122.58)

* Green energy is not completely carbon free

("EV" is an abbreviation for "electric vehicle," Lake Drive is a road on which many commuters travel to campus, the "Rapid" is the local bus service, and "Temperature Drop" refers to reducing the temperature of campus buildings in the winter by 3 °F.)

How CCCN Informed the Campus Community {C}

The first way in which the CCCN project informed the campus community was administratively. The Vice President for Administration, Finance, and Information Technology attended all the oral presentations and received a copy of the final written report. His active participation supplied meaningful direction to student efforts and kept things focused on the educational, administrative, and financial impacts of moving toward carbon neutrality.

Beyond this formal administrative impact, the project added momentum to campus conversations about sustainability that were underway long before the Fall 2007 semester. Results of the CCCN project were presented at the Fall 2007 Calvin Environmental Assessment Program (CEAP) poster session, where other administration personnel and faculty members became aware of the results of the student project.

Assigning this project in the Fall of 2007 with final presentation occurring in early December 2007 offered a primer for the campus community before our Focus the Nation[10] activities (January 2008). Building upon the momentum from Focus the Nation, consensus arose that a good next step would be to institutionalize campus-wide commitments to creation care and sustainability. So, in April 2008, the faculty Environmental Stewardship Committee (ESC) presented a proposal to the college administration, suggesting a two-year trial of a Sustainability Director who would coordinate the many sustainability activities on campus. In the summer of 2008 (after the Sustainability Summit—see below), the provost awarded teaching release time to a faculty member for sustainability work on campus.

Given the overwhelming interest in Focus the Nation events on campus, several faculty members organized a follow-on Sustainability Summit[11] for faculty, staff, and administration in May 2008. At the summit, small groups discussed Calvin's Statement on Sustainability,[12] shared ongoing efforts toward sustainability within existing campus administrative units, and developed nonbinding sustainability action plans. Several concrete action plans were developed during the summit. Some items on those plans included (1) creating a bike path along Lake Drive (now in planning discussions with the bordering municipality); (2) requesting that the college president attend the President's Climate Commitment Conference (which he did); and (3) improving utility metering for campus buildings (now in process).

While it is difficult to directly link the carbon neutrality project to advances in campus sustainability, this effort certainly was a contributing factor, and it provided significant continuing momentum for ongoing campus conversations. The project was recognized and valued by other local colleges as well as city officials. This work, together with the various initiatives that have been spawned in its wake, have given our college increased credibility in the broader sustainability dialogue in our region.

Carbon Emissions Trading Simulation (CETS) {D}, {E}, and {G}

Two-step Process

The Carbon Emissions Trading Simulation (CETS) was intended to provide a kind of "carbon lens" through which students could recognize their daily complicity in global climate change {E}. We also hoped this activity would help students better understand the dynamics of carbon markets and carbon trading {D}. The simulations began with each student given an allotment of carbon credits and a set of daily activities with associated carbon credit costs (p. 93) to be used over the duration of the simulation. Whenever students engaged in an activity, they were required to retire the associated carbon credits from their total. Participants who retired all of their carbon credits before the end of the simulation were required to purchase credits (with real US dollars) from participants who maintained a surplus. Carbon credit pricing was never explicitly set; instead we allowed our simulated markets to determine the credit price. At the end of both market simulations, participants who made the most money submitted their profits to finance a pizza lunch.

Carbon Credit Tables

The market for CETS version 1 (v1) was based on a cap-and-trade system using allowance-based transactions among students and faculty.[13] Each participant was assigned 110 carbon credits[14] on the first

day of the simulation. (Credits were manifested as Monopoly® money dollars, i.e., 110 carbon credits = 110 Monopoly® dollars.) During the first version of the simulation (two weeks), carbon emission credits were activity-based rather than mass-based (Table 2).

Table 2. Carbon Credit Equivalence of Market Participant Activities (CETS v1)

Credits	Activity
2	Ride in a car on a one-way trip anywhere: to campus, to the store, home, etc. (Two people the same car retires one credit per person.)
1	Watch TV for an hour. (Two people watching the same TV retires 0.5 credits per person.)
6	Operate air-conditioning in your house for a day. (No pro-rating for housemates.)
4	Operate the furnace in your house for a day. (No pro-rating for housemates.)
1	Eat a piece of fruit grown outside Michigan.
1	Use or leave a computer on for 2 hours.

CETS version 2 (v2) was designed by students to be a mass-based simulation (Table 3) and therefore closer to how real carbon markets[15] operate. One carbon credit was roughly equivalent to one-half pound of CO_2 emitted. For CETS v2, each participant was given 1600 carbon credits at the outset of a six-week simulation. Carbon credits were assessed according to the table below. Note that two activities allow students to add carbon credits to their account.

Market Tracking Systems

Keeping track of every student's carbon-emitting activities each day was a significant challenge. For CETS v1 we had students fill out a report slip and turn it in each morning, detailing the carbon cost of the previous day's activities. Our administrative assistant constructed a large class database on which she daily kept track of all the individual student accounts. This system was greatly improved by implementing a Google Docs automatic tracking system for the second version of the simulation. Accounting through the Google Docs website allowed students to not only see their own carbon account, but they could also access an updated summary of the overall market of carbon credit behavior for the class (number of credits retired, earned, or traded). This second accounting system, which the students themselves devised, proved to be a significant improvement over the original tallying method.

Individual Behavior Implications {E}

We guided discussions throughout the semester to reinforce two key notions: (1) humans count what they value and value what they count and (2) accounting systems change behavior. Regarding counting things of value, because of the visibility of the Monopoly® money, CETS v1 created a bit of a buzz on campus, and many nonparticipants were discussing the simulation. The play money was a visible signal that something of value was being counted. Market participants noted that the simulation caused some inconvenience, as (a) they were required to monitor their own behavior at an unaccustomed level of detail and (b) taking action to reduce their personal carbon footprint required lifestyle changes.

Table 3. Carbon Credit Equivalence of Market Participant Activities (CETS v2)

Credits	Activity
40	Consume 1 gallon of unleaded gas in a car (20 credits if you carpool)
1	Watch TV (2 hr)
1	Play video game (1 hr. includes having TV on)
80	Operate AC (1 day)
40	Operate Furnace (1 day)
4	Eat a piece of fruit from outside Michigan
40	Eat meat (1 lb beef)
1	Use or leave a computer on (2 hr)
12	50 lbs trash
14	Machine-dry clothes
-10	Install fluorescent light bulbs (saved per light bulb)
-100	Plant a tree (2 ft tall) linear scale: 1 ft = -50 credits

Regarding behavior changes, students reported the following changes in response to participating in CETS:

- Walked, ran, biked, and carpooled more often to campus and grocery stores, because walking, running, and biking counted for zero credits while carpooling reduced credit cost for commuting.
- Watched movies on their computer instead of on a TV, because computer use counted for fewer credits than TV watching.
- Delayed laundry until larger loads were possible.
- Watched TV with friends so they could split the credits.
- Organized tree-planting activities, because that generated credits for the planters.
- Chose to eat locally grown fruit when possible.

Through CETS, students came to grips with the difficulties of achieving carbon neutrality in their own lives. A few comments from student evaluations illustrate this point:

> The CETS simulations helped me to understand how my everyday choices affect my carbon output.
>
> CETS has taught me how much carbon I personally contribute on a daily basis and how nearly impossible it would be for me to eliminate all my carbon emissions.
>
> CETS made me very conscious of the fact that my actions have a consequence not only on myself but also affect the environment, climate, and the survival of organisms around me.
>
> CETS taught me the value and effectiveness of limiting consumption instead of striving to remove harmful emissions retroactively.

Market Behavior {D}

CETS provided enough realistic structure to allow real-life market behaviors to emerge during the simulation. Figure 5 shows credits retired and credits traded over time during CETS v2.

The left graph of Figure 5 shows that as the weather turned colder, market participants tripled the daily rate at which credits were retired, due mostly to increased household heating. The right graph of Figure 5 shows that at the outset, very few market participants thought they would need additional credits at the end. Thus, no trading occurred in the early part of the simulation. However, at the end, market panic set in, and feverish trading took place in the last days.

At the beginning of CETS v1, students quickly "discovered" the concept of market speculation. Shortly after hearing the rules for the simulation, one student asked, "Can I buy credits now (at a low price), even if I know I won't need them at all, just so I can sell them near the end (at a higher price) and make a profit?" The answer, of course, was "Yes." And, we were able to point out that speculators take similar actions in other markets.

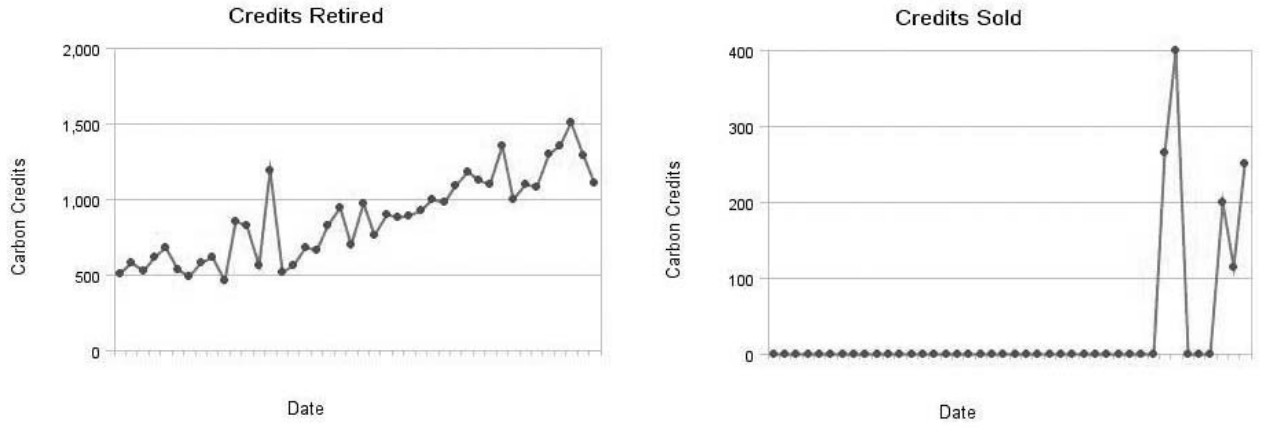

Figure 5. Carbon credit retiring and trading activity.
(Each tic on the horizontal axis represents one day of the simulation.)

We also had an instance of insider trading. Midway through CETS v1, one professor discovered which students had a surplus of credits remaining. Then, he emailed the credit-rich students asking them to compete amongst themselves for the lowest sale price. However, the CETS rules did not include a reporting mechanism obliging market participants to reveal the quantity of credits they held. So, in effect, the professor was using privileged information to manipulate the market to his advantage: insider trading. We used this example as a springboard for discussing the ramifications of insider trading in real markets.

We also had claims of injustice. Like real markets, the rules of CETS were set up to the advantage of some participants and the disadvantage of others. Several students who lived farthest from campus experienced this first-hand and raised the issue. Was it fair, they asked, that the deck was stacked against commuters? We used the commuting distance issue to discuss with students how humans always create the rules under which we are supposed to live, whether those rules are for markets, for politics, or for highways. Those rules are never value-neutral. And, markets are never really "free"; they are always constructed.

Many students noted how the mere fact of having a system that counted their behaviors increased their awareness of those behaviors. Because of the CETS structure, competitiveness caused students to adjust their behaviors in ways that reduced CO_2 emissions. We had different winners for each version of CETS. Both winners succeeded because they lived on campus and made a concerted effort to reduce their activities that led to carbon emissions.

How CETS Informed CCCN {G}

Although not designed explicitly to do so, the trading simulations had a profound effect on the carbon neutrality project {G}. Through the simulation, students became sensitized to those aspects of their daily lives that were most costly in terms of carbon emissions. They were also able to experience the relative difficulty (or ease) of altering behaviors to decrease personal emissions. This effect was most noteworthy in the area of transportation. During the simulation, we noticed a high percentage of our students riding bicycles to campus. Several commented this was not nearly as difficult a transition as they had expected. This experiential backdrop likely contributed to students' suggestions in the carbon neutrality project for more bike lanes and safer bicycle entry points to campus, as well as other transportation-related changes. The simulations, in a sense, gave students the opportunity to "try out" altered behaviors within the relatively safe context of the simulation. These altered behaviors led to informed recommendations for the carbon neutrality action plan.

Impacts

Novel teaching approaches such as those described here carry with them significant risks. The potential for both favorable and unfavorable outcomes is palpable. Some of the positive outcomes we identified for students and faculty/administration are described below.

How the Project Impacted Students

The experience of the CCCN and CETS exercises had many beneficial impacts on students. First, course evaluations indicate that they came to a deeper understanding of climate change issues and possible solutions. One student wrote,

> I now believe that mere technical advances cannot alter the course on which we are heading. I believe that if there is any hope for achieving carbon neutrality, major lifestyle changes need to be made.

The project also deepened personal commitments among several students. One way we saw this expressed was by more intentional active involvement on campus. One of the ecology students agreed to become a resident assistant for a new intentional community dorm floor on campus that will focus on Creation Care.[16] Another student became very active in campus environmental issues and was hired by the college as project manager for a major college forest mitigation and naturalization effort.[17] And a student interested in international development helped organize a week-long workshop on Creation Care in Missions that included faculty and students from the International Development Studies Program.

For other students, involvement with CCCN and CETS was an opportunity for individual growth. One engineering student exhibited emergent leadership skills throughout the CCCN project. He used the project as an opportunity to develop skills at

planning, organizing, and motivating. Through his amiable personality, intellectual competence, and continual encouragement, he became the de facto leader to whom others looked for guidance. He took personal responsibility to ensure that groups were communicating essential information. He invested heavily with time and hard work to make the final report as good as possible. This student had the opportunity to develop these skills precisely because the open-ended structure of the project was so different from traditional classroom learning. On end-of-semester peer evaluations, he was unanimously commended for his supererogatory efforts.

By the end of the semester, students understood the value of interdisciplinary cooperation. Here are some of their comments.

> Through cooperation between classes, I realized more that reducing carbon emissions will require an effort from all fields, not just engineering.
>
> The lesson I learned from [the biologists] is that coming up with a solution to a problem does not entirely depend on calculations. In my opinion, the biologists came up with more creative ideas on how to make Calvin's campus carbon neutral.
>
> Engineers viewed the situation as a problem that we are to find a solution for. The biologists viewed it as a learning opportunity. They viewed it as an opportunity to get the public to see the effect they are having on the environment. I think both views are important.

How the Project Impacted Faculty and Administration

This project was a tangible reminder to us that students are much more than simply learners (academic model) or paying customers (business model). Instead, students are better thought of as participants (community model) with vested interests in the place in which they become educated and develop community.[18] Given opportunity and encouragement, students can contribute significantly to their college place and can be conditioned to seeing the value of investing in whichever place and community they eventually reside.

This experience was also a valuable lesson in the importance of varying teaching approaches to cater to all types of learners. We observed several students flourish in this learning context who had previously been challenged by traditional pedagogical approaches. Other students with great aptitude for memorization and individualized learning were more challenged by this activity. It was a strong reminder to us of the importance of offering a variety of learning experiences to accommodate the variety of students that we encounter.

Not knowing the outcome of this assignment a priori, we found our own expectations to be seriously inaccurate with regard to the balance of carbon emissions and carbon sequestration on a campus such as ours. It was very surprising to us how difficult it is to achieve carbon neutrality, in our personal lives and at the institutional level. But having an informed understanding of this goal is critical to developing a meaningful strategy for achieving it.

The element of this project that surprised us most was how little carbon sequestration is possible on our campus. We each had a sense that sequestration (planting trees) would be an important element of a plan to achieve campus carbon neutrality. However, student calculations clearly showed that filling all available campus space with trees would have minimal impact, given our current emissions levels. We learned that decreasing emissions is a far more important driver in attaining carbon neutrality than increasing sequestration capacity.

This classroom project allowed us to expand our impact on campus and in the broader community regarding sustainability and climate change issues and to develop our voice regarding climate change and sustainability in general. Since the CCCN project, we helped organize Calvin's Focus the Nation[19] activities, participated in planning the first-ever Calvin Sustainability Summit,[20] and spoke at the Faculty Conference in the following autumn. Beyond the campus, we presented this project at the 2008 Association for the Advancement for Sustainability in Higher Education (AASHE) conference and were asked to lead a half-day workshop on sustainability related to economic development for an international development organization.

One final unforeseen lesson learned was how disciplinary identities and characteristics are already firmly established among third- and fourth-year

students. Ecology students frequently commented how differently they approach a project like this, when compared with their engineering counterparts. Engineering students made similar observations about the ecology students. The important lesson we take from this effort is that students who remain largely within the comfortable confines of their chosen discipline will be less-equipped to meaningfully address interdisciplinary challenges such as climate change after graduation. We believe experiences such as this are invaluable opportunities for preparing our students for post-college vocations.

Conclusion

Climate change caused by global warming will have a significant impact on today's students throughout their lifetimes. International and institutional actions will affect the personal decisions they will make after they graduate. Any activity that involves consumption of energy will be affected: where should I live? what house should I buy? what transportation options will I use? etc.

Many students began the CCCN project with a sense of bewilderment at what they were expected to accomplish in the semester: they had never before been asked to work on such a large and coordinated project. Mid-way through, many students expressed frustration at the lack of direction for the open-ended project: no one could tell them how to achieve carbon neutrality. But in the end, their efforts coalesced into a very fine final product of which everyone was justifiably proud.

Along the way, the CCCN project evolved from a group assignment to a collective responsibility. There are several reasons for the evolution, none of which are necessarily tied to the topic of climate change:

- student names were attached to the project;
- the results were very public due to the poster session, campus-wide seminar, and the final report being posted online;
- the project was *big* and attracted a lot of attention; and
- the college administration was involved, which made it seem to students that their ideas could be implemented.

We sought to expand our students' understanding of the impact that climate change will have in their lives through three types of instruction (traditional lectures, a group project [CCCN], and a participatory simulation [CETS]) that addressed multiple levels of student inquiry (global, institutional, and personal). Instructor and student evaluations indicate that this approach was successful on all three levels of inquiry. Students reported a deeper understanding of global issues related to climate change; the project has had a positive impact on our educational institution; and students reported increased awareness of how personal decisions interact with both institutional and global dimensions of the problem. There are significant risks involved with this type of teaching, not least of which is the possibility of public failure. But the rewards in terms of student success through self-motivated learning in a group setting can be very significant for both students and professors. The goal of campus carbon neutrality provided a rich topic in which these rewards were realized.

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Resources

Classroom materials for this project can be found at www.calvin.edu/~mkh2/cccn/. Resources include the assignment given to students, details of CETS, student posters and presentations, the final report, and student project assessment questions. Readers may use any of the resources provided that attribution is given to the authors in any published works.

Notes

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