

Collaborative research with K-12 students on impacts of climate change on ecosystems in an environmental engineering service-learning course

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ABSTRACT: This article focuses on the first offering of an innovative civil and environmental engineering service learning (SL) course entitled CEE58SL Climate Change, Water Quality and Ecosystem Functioning: A Service Learning Course. This five-unit course involved academically rigorous learning at the University of California Los Angeles (UCLA) on climate change and its impacts, as well as a substantial commitment of time devoted to working with K-12 students (two field trips and four classroom visits). In the first part of the SL component, conceptual models illustrating key concepts of climate change (trapping of heat by atmospheric gases and different reflectivity of Earth's surfaces) and ocean acidification from increased carbon dioxide in the atmosphere were used as hands-on classroom activities. Students then did research on relevant, grade-appropriate topics using the Internet and books, created posters of their results, and presented their results at the University.

INTRODUCTION

The service learning (SL) pedagogy is generally defined by the integration of academic subject matter with community needs [1][2], and its adoption in engineering is increasing [3-8]. Ideal service learning courses consist of clearly articulated learning objectives, identified community needs (which the service learning aims to address), a community voice in projects, and student opportunities for meaningful participation, as well as guided reflections.

Service learning has had a multitude of positive impacts not only on students but also on teachers and the surrounding community. With regard to academic learning, SL courses have been shown to increase student mastery of technical objectives and critical thinking skills [1][9-12]. In addition, students in SL courses have reported a higher rate of course satisfaction [13] and improved attitudes to the subject matter [14]. Partnerships between universities and K-12 classrooms are on the rise and offer educational and mentoring benefits for students at all levels, particularly when the SL addresses community needs and material is integrated into the curricula [15-17]. In the case of this course, K-12 teachers with whom the authors worked had identified a need for hands on science and research opportunities on climate change.

Teaching the science of climate change at the University level lends itself especially well to a service learning (SL) component. Too often climate change is seen as something that will occur in the future, even though there is scientific consensus that climate-induced change is already occurring; the only controversies today concern the level of climate change and impacts. Adding an off-campus component to climate change courses makes the topic more tangible for university students. In addition, it is important for a well functioning democracy that all educated citizens, not just science and engineering majors at universities, grasp the science of climate change to the extent that they will be confident in forming their own opinions on this topic. Thus, involving university students in the teaching of climate change science to K-12 is a natural fit.

This article focuses on the first offering of an innovative designated service learning course entitled CEE58SL Climate Change, Water Quality and Ecosystem Functioning: A Service Learning Course. This five-unit course involved academically rigorous learning at the University of California Los Angeles (UCLA) on climate change and its impacts, as well as a substantial commitment of time devoted to working with K-12 students (two field trips and four classroom visits). This course also offered general education (GE) credit, and was the first SL course in the School of Engineering. University and K-12 students worked collaboratively on grade-appropriate research projects on the impacts of climate change on water resources and ecosystem functioning.

In this article, the authors will: 1) give an overview of the first offering of CEESL Climate Change, Water Quality and Ecosystem Functioning: A Service Learning Course, the first SL course in the UCLA School of Engineering; 2) present

excerpts from reflections from UCLA students working with middle school students; and 3) describe the results of an anonymous survey of the UCLA students.

COURSE OVERVIEW

The University of California Los Angeles (UCLA) is a large (> 27,000 undergraduate and > 12,000 graduate students) public university with a strong commitment to civic engagement. The University's Center for Community Learning was created to assist students and faculty (academic staff) across departments with SL and internships and has created a minor in Civic Engagement. The course described here is a General Education (GE) course with a rigorous academic component on the impacts of climate change on water resources and ecosystems. For SL course designation at the University, 20 SL contact hours and self-reflection writings are required. For this course, the hours were spent working with K-12 classrooms on research projects pertaining to the subject matter. The goals for University students were to enhance learning on the subject matter and to offer an opportunity for civic engagement. The goals for the partners were to supplement the science curriculum with hands on activities and to provide a small-group research opportunity.

The instructor is an Associate Professor in Civil and Environmental Engineering specialising in coastal water quality and metal pollution in water. Other courses include aquatic chemistry, reaction and transport of chemicals in the environment, geochemical modelling and sustainability. This spring was the first offering of the course, and it reached its enrolment cap of 25. Almost all the students were non-science majors. Eighty-one K-12 students in four different classrooms participated in this project.

Material was presented to the undergraduate students in several different ways in order to facilitate a deeper understanding of the elements crucial to the course, and offer experience in skills that would be useful for teaching to the K12 students later in the quarter. Readings for the course were drawn mainly from three sources: a text book entitled *Environment, The Science Behind the Stories* by Withgott and Brennan, reports from the Intergovernmental Panel on Climate Change (IPCC), and the Climate Change Science Compendium (CCSC). The IPCC is a group of over 1,200 scientific experts and their reports constitute a scientific consensus on the state of the science of climate change and its impacts. The CCSC provides a summary of current research released since the last IPCC report.

Short quizzes were administered in the first part of each class to help solidify important concepts from the readings. Topics were further explored through a short lecture and class discussion to engage all of the students. The remainder of each two-hour session (over an hour each day) was spent on active, small-group learning. For example, on one particular day, eight groups of two to four students worked together for one hour to create presentations of the impacts of climate change on various types of terrestrial ecosystems. Each group then gave a mini-presentation to the class, which served as practice for presenting/teaching to K12 students. Students were also required to write two short papers, each describing a case of documented or probable impacts of climate change on water resources or an ecosystem. Wherever possible, papers were required to draw upon three primary literature articles to gain experience with data and literature mining that would become important in guiding K12 students.

For the SL component of this course, the authors worked with three schools: Roosevelt Elementary School (two 2nd grade classrooms), St. Anne's School (one 7th grade class) and Flintridge Preparatory High School (one 12th grade class). At St. Anne's, the student body is composed primarily (97%) of students from minority groups that are underrepresented in science and 70% of the students qualify for free hot lunch. The school is in need of hands-on science enrichment, and the authors have had a long-standing (ten-year) SL partnership with the teacher at this school. For this course, the authors began new partnerships with the other two schools based on existing relationships with the teachers and desire of the teachers to incorporate climate change science into their science curricula.

Preparatory work prior to classroom visits: A former high school science teacher, currently a PhD student at the Graduate School of Education and Information Studies, visited the UCLA classroom to give the students tips on working in small groups with K-12 students. She trained them in how to engage the students in discussion by asking questions rather than simply transmitting information.

The instructor gave students fifteen slides introducing climate change and its impacts. Pairs of students were tasked with adapting the slides to be part of an inquiry-based presentation appropriate for the grade level with which each pair of students would be working.

Session 1: First Classroom Visit. Introduction to climate change and solar oven project. All introductory material on the science behind climate change and current known impacts on water and ecosystems were presented to the K-12 children in small groups as part of discussions mediated by the University students. After a brief discussion, each small group built a solar oven using a pizza box following a design available on the Internet (<http://kitchenpantryscientist.com/?p=313>). Briefly summarised, students cut a flap in the top of a pizza box and covered it with tin foil. They, then, covered the rectangle in the cover created by the flap by clear plastic wrap on both sides, creating a double layer. Inside the box, they taped coloured paper on the bottom to serve a heat-absorptive surface for the food. K-12 students made s'mores (chocolate and marshmallows are melted between graham crackers) and cooked them in the ovens.

This activity presents two very important aspects of global warming and the benefits of solar energy as a power source in a very accessible way. Students are able to see the sun cooked the s'mores as an example of the use of renewable energy, and they also see the trapping of heat that is happening on Earth as the concentration of greenhouse gases increases in the atmosphere. Conceptual models such as a *blanket* were used to explain the layer of GHG in the atmosphere that results in increased heating when it *thickens* (the levels of GHG increase). These conceptual models were reinforced by comparisons to the pizza ovens the K12 students were using. For example, the GHG blanket on the Earth was compared to the clear plastic wrap layer in the top of the oven. The principles of reflectivity (the tin foil used to direct the sun) and increased absorption by darker colours (the black paper lining the oven), important in the science of climate change, are also demonstrated by this activity and were emphasised by the University students. Specifically, the students learned that sea ice (lighter in colour than the surrounding ocean water) plays an important role in reflecting some of the sun's rays.

Session 2: Second Classroom Visit. Ocean Acidification Experiment. The goal of this visit was to teach the K-12 students about the concept of acidity, the pH scale and how excess carbon dioxide in the atmosphere can also cause ocean acidification when it dissolves in water. Working in the same small groups, University students assisted K-12 students in making a pH indicator out of cabbage by tearing cabbage leaves and soaking them in hot water. K-12 students, then, created duplicate tubes of acidic and basic solutions using lemons and dish soap, and discussed the concept of acidity. They, then, added a small amount of the indicator to each of the tubes and observed the different resulting colours. UCLA students, then, explained to them that when carbon dioxide dissolves in water, it actually reacts with a water molecule, resulting in carbonic acid or H_2CO_3 , according to: $CO_2 + H_2O = H_2CO_3$. Students, then, blew through straws and observed the colour in the tubes shifting toward a more acidic colour due to the carbon dioxide in their breath.

Session 3: Field Trip to the Aquarium of the Pacific. All four K-12 classrooms and UCLA students went to the Aquarium of the Pacific to tour the aquarium in small groups and see the special exhibit on how climate change is having an impact on polar regions. Prior to the trip, UCLA students had reviewed and summarised photographs of the aquarium's exhibits, so they were ready to direct their group to particularly interesting exhibits and could focus on leading their groups rather than reading the text of the exhibits themselves.

Sessions 4 and 5: Classroom Visits for Research Projects. Grade-level appropriate projects (based on state educational standards and conversations with teachers) were conducted in small groups in all four classrooms over two classroom visits. Each group of second graders chose a favourite animal and researched the impacts of climate change on the habitat of the animal. Middle school students used weather data available on-line to research climate trends in a city of choice (this project had been piloted by the high school teacher in one of his courses the previous quarter). High school students analysed California snow pack data to observe trends that could have an impact on the freshwater supply in the state. Results of each group's research project were summarised on a Power Point slide and printed as a large poster.

Sessions 6: University Day: Panel and Poster Presentation. K-12 students visited the University and participated in three components: 1) Panel on college life. UCLA students served as the panel and middle school students were free to ask questions about pathways to college, life as a college student, etc. Even though the students had been getting to know each other informally all quarter, this provided an opportunity for the middle and high school students to delve into questions and generated a lively discussion; 2) Campus tours. Students toured the campus together in their small groups. Tours were tailored to the students' interests; and 3) Poster session. All K-12 students were able to present their findings to faculty and students.

REFLECTION

The SL experience is most educational when reflection guides the student to develop a new understanding of the situation, which, in turn, leads to a change in state of mind and more informed action [18]. The *small moments* writing strategy to foster reflection in the University students was employed, as it has been shown to build awareness leading to insight, allows students to identify discrepancies and solve problems, and bolster confidence [19]. After every interaction with K-12 students, University students were asked to describe the details of an occurrence during their work and, then, give their interpretation of it.

Excerpts from UCLA Student Reflections

Table 1: Selected reflections from the CEE58SL students.

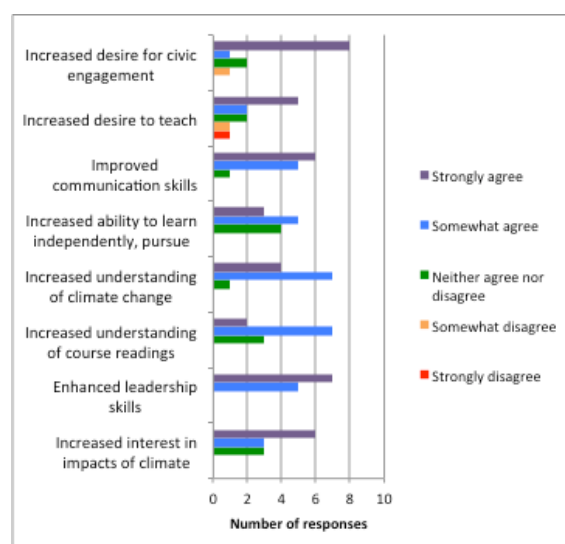
Topic	Selected Reflection
In-class hands on activities	At the beginning of this whole process, I was pretty nervous about being caught off guard, or not knowing some of the needed information. I was a little intimidated by being in the middle school environment again, but after going over a few slides with my group, all my irrational worries disappeared. I really enjoyed teaching the students and making the solar oven. It seemed like they had a good time making it, which made me feel as if the day was successful.

	We reviewed how we talked about increasing amounts of carbon dioxide in the atmosphere during the power point presentation the week before and how it is not only leading to global warming, but also ocean acidification. We explained how we could demonstrate this by blowing into straws into the test tubes because we exhale carbon dioxide.... The students were very excited to do everything that was hands on and seemed to really enjoy the experiment.
On field trip	Visiting the aquarium was a great opportunity to engage the students in the topics we have been learning about it was one of my favourite experiences.
On the poster-making sessions	This was the most exciting of all the visits for me. The students really portrayed an immense amount of talent, creativity and intelligence. First, I showed them the slide prompt, and we decided where to put all the information and pictures. They had the idea to lay out the poster like a play. They all wanted lines to perform at the presentation. I am really glad that the research poster took more than one visit because it made the students feel like it was something that they had been working hard on and were proud to present!
University Day	The best part of this class and this day was it makes [the University] seem to be an achievable goal for them. Growing up I never thought I would be at such a great school. The students all asked really good questions about dorm life....
On bonding and mentoring	Just before leaving, [a student] pulled me aside to thank me for being so nice to him and defending him from the students who would sometimes made fun of how he wanted to go to an Ivy League.... Overall I thought this was a great experience, I bonded and made great friendships with many of the students.
Overall experience	This class as a whole was more exciting than a basic lecture GE. We were literally on our feet and creating the class as we went along.... I need to be exposed to what is around me, and understand what it means to be a citizen of earth. The students and the class were very inspiring. I definitely enjoyed working with these students and teaching them about important environmental issues. They are the future of our planet and getting to teach them about climate change and the importance of preserving our natural research made me feel like I was making a difference. Overall it was a great quarter!
Personal growth, changes in goals for University students	This class was one of the most inspiring classes I have taken at [the University] thus far. As science is not quite my forte, I not only learned a lot about climate change in simple terms, but I was able to then forward my knowledge to others. To be honest - as a Political Science major - I have always felt that changes are made with progress in the policy changes of the adult world. However, after interacting with the students for nearly a quarter, I am inspired to become more involved with establishing an early awareness of social issues in the K-12 sector.

Survey Results

Assessment consisted of an anonymous, optional survey of the University students after grades were turned in (students were informed their responses would be used for a paper about the course). IRB determined that our post-course anonymous survey was allowable for use in a publication. In the post-course survey of UCLA students, twelve students responded out of 22 who were contacted (three students did not have finalised grades). Half or more respondents chose *Strongly agree* to the statement that the service-learning component of the course resulted in increases in their communication and leadership skills, as well as an increased desire to become involved in civic activities and an increased interest level in the impacts of climate change.

Figure 1: Results of anonymous post-course survey of University students about their perceived benefits of the course.



CONCLUSIONS

This work describes an innovative designated Service Learning (SL) course involving collaborative research between K-12 and UCLA students on the impacts of climate change. UCLA students were able to develop successful mentoring relationships with K-12 students through repeated sessions working in the same small groups. Grade-level appropriate environmental research using the Internet was the focal point of the work, and students gained experience in analysing and presenting results.

In a post-course survey of UCLA students, half or more respondents chose *Strongly agree* to the statement that the service-learning component of the course resulted in increases in their communication and leadership skills, as well as an increased desire to become involved in civic activities and, an increased interest level in the impacts of climate change.

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