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Incorporating service learning in traditionally lecture-based environmental engineering courses through researching bacterial contamination at a local beach

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ABSTRACT: The objective of this study was to determine the efficacy of an optional 1-2 unit service learning (SL) course added onto two undergraduate engineering classes. The SL add-on aimed to increase participant understanding of, and interest in, local environmental science issues relevant to the course material and consisted of classroom visits to a partnering middle school class, collaborative environmental field research to test student-generated hypotheses, and presentations of the results at the university. Letter writing about environmental issues was included as a political engagement opportunity for the middle school students some years ago. For undergraduates, the SL component resulted in increases in the undergraduates' perceptions of both their level of knowledge about politics and of their role in government. A similar survey was administered to middle school students, whose results were less consistent across both years. In the post-survey in 2008, middle school students reported increases in their perception of the importance of understanding science and their interest in local government. These results show that even the addition of an optional SL component can provide value to both the community and the undergraduate students.

Keywords: Service learning, community-based research, water quality, political engagement

INTRODUCTION

Service learning (SL) is a form of experiential learning that integrates academic subject matter with community needs; key elements include reciprocity, reflection and a community voice in projects [1][2]. SL courses have been shown to improve mastery of technical objectives and critical thinking skills [1][3-6]. In addition, students in SL courses have reported a higher course satisfaction [7] and improved attitudes about the subject matter [8]. Having been well-established over the last three decades in other disciplines, SL is now increasingly being adopted in engineering [9-14]. This article describes how a SL component was offered as an optional add-on to traditional lecture-based engineering courses.

One important benefit of SL is that it helps students navigate complicated novel concepts through educating others and experiencing a real-world context for the course material [15]. In pre- and post-activity surveys, SL components have been shown to increase students' understanding of course concepts [3] or to increase their feeling that they made progress toward gaining knowledge [8]. In addition to greater understanding of the course material, SL can produce more intangible benefits for students as well. Student ratings of the field of study, course, and instructor all increased after an SL component [8], and SL components show some impact on behaviour and appreciation of the environment when that is included as a focus of the SL activity [3][8]. Even very short-term SL can create a change in student opinions; in a study with only 8-10 hours of SL significant improvements were seen in an appreciation for college and interest in a service-related occupation. Partnerships between universities and K-12 classrooms offer educational and mentoring benefits for students at all levels, particularly, when the SL addresses a community's needs and material is integrated into the curricula [16-18].

One additional aspect that was incorporated into the SL components described here was that of community-based research (CBR), which involves collaboration on research projects between faculty (academic staff), students and community partners. CBR is a growing and significant component of the community-engagement efforts at institutes of higher learning [19-21]. One of the basic principles of CBR is that it is a true collaboration between the involved parties, rather than the community serving as a *laboratory* for academic research. In order to bring in the practices of both CBR and SL in the department, the add-on course was structured so that university students would visit middle school classes to develop research ideas in collaboration with the middle school students rather than providing the hypotheses. Under the guidance of university students, middle school students worked together in teams to develop hypotheses, conduct research at local field sites and make posters of the results. Middle school students were then invited to UCLA to tour the campus and present their results at a poster session. The objectives of the SL programme were to increase interest in science and environmental issues among the middle school students. There were mentoring benefits as well for both the middle school students and the university students, due to the focus on small group work with consistent mentors. This study focuses on the addition of an optional service learning laboratory that can be added to a required course, which is different from other studies that look at a service learning component integrated into a course.

In this article, the authors will: 1) give an overview of this add-on model for incorporating SL in traditionally lecture based environmental engineering courses at UCLA; 2) describe two years of results of an Institutional Review Board (IRB)-approved survey of participating middle school students; and 3) present excerpts from reflections from university students working with middle school students.

METHODS AND PROGRAMME OVERVIEW

Partnering Schools

For the optional add-on model for SL, the authors worked with two middle schools: St Francis X. Cabrini and St Anne's Schools. Both schools serve a population that is over 95% Latino with 70% of the students qualifying for reduced hot lunch. Schools were chosen based on both demographics, as one goal of the programme was to encourage students from minority groups underrepresented in science and engineering to pursue this field, and the need for supplementary resources for science education.

Description of Add-on Model of SL

For 10 years, a subset (between 12-30) of UCLA students in CEE166A Environmental Microbiology or CEE154 Chemical Fate and Transport in Aqueous Environments also enrolled in optional one- or two-unit course to work with middle school students on an environmental research project. First, these university students were given some background in local coastal water quality and required to read a literature paper on this topic. They were, then, trained by graduate student researchers in the instructor's laboratory in the techniques they would be required to teach to the middle school students. The main technique required for this project was to measure faecal indicator bacteria (FIB), which are used to assess the microbial quality of recreational waters. After learning the needed laboratory techniques and background information, university students participated in a series of four weekly sessions with middle school students to share this knowledge with them.

Session 1: At the first meeting, which occurred at the middle school, undergraduate students were joined by small groups of middle school students, who would be their students for the remainder of the SL component. For the first twenty minutes of the hour-long visit, undergraduates discussed concepts in microbiology with their groups and led the microbe safari, which is a self-directed experiment, where middle school students collected bacteria from the environment and cultured them (further described below). This *icebreaker* activity provided a hands-on or tangible opportunity to familiarise middle school students with general microbial techniques, prior to the water quality-oriented project of collecting and culturing specific bacteria from the environment to answer a scientific question.

For the microbe safari exercise, each seventh grader was given a Petri dish to grow bacteria from two samples, such as from their hand before and after washing, or from the bottom of their shoes and socks. Middle school students were encouraged to propose simple hypotheses, such as *My hands will have fewer microbes after I wash them, compared with before,* or *...the bottom of my shoes will be much dirtier than my hands*. Creativity was encouraged and prizes were sometimes offered for the plates that grew the most bacteria or that showed the most interesting results.

For the remainder of the one-hour session, after middle school students collected their microbe safari samples, each group of university and middle school students discussed the beach water quality project that would be the main focus of the class thereafter. Together, they studied aerial photos of the field sites that would be sampled (locations included Mother's Beach in Marina del Rey, the Santa Monica Pier and a large storm drain on Santa Monica Beach) and discussed known information about bacteria levels in water and sand at that site. Previous field research in the laboratory had found the areas underneath Santa Monica Pier and close to the storm drain to be consistently contaminated with FIB, with concentrations generally decreasing with distance from the Pier or storm drain. Undergraduates also presented general information about FIB, including their increased ability to survive in sand over water due to factors, such as decreased solar inactivation [22] or increased protection from predators [23].

Following these presentations, each middle school group brainstormed (with guidance from undergraduate group leaders, as needed) to come up with their research question, hypothesis (see Table 1) and research approach. University students familiarised middle school students with the materials that would be used during sample measurement at the beach field site (field kits containing measurement materials were brought to the class). Field kits were comprised mainly of easily purchasable items, such as small spray bottles to sterilise with ethanol, measuring spoons to add the correct amount of sand for processing, a plastic box with lid to hold kit and instant hand sanitising gel to clean up after processing the samples.

Table 1: Research hypotheses generated by student groups after a brief background on contamination of the site.

Group	Hypotheses created by student groups for research projects
1	The researchers investigated the hypothesis that bacterial levels would be higher near the storm drain outlet. They also wanted to find out if bacterial levels in the sand under the pier, since it is always shady, were higher than sand exposed to sunlight.
2	Bacteria levels will decrease with depth because the exposure to the water decreases.
3	The researchers believe that bacteria levels are higher underneath the pier because there is no sunlight and there are bird droppings adding to the contamination.
4	The researchers investigated the hypothesis that bacteria were coming from a small pool under the pier, caused by a storm drain.
5	The researchers investigated the question: are there any bacteria in the sand and how many are in the sand?

Session 2: For the next session, university students met the middle school students at the field site where they spent two hours collecting and analysing samples. Middle school students gained hands-on experience processing and analysing samples at the beach. To measure Escherichia coli and enterococci in water samples, middle school students diluted water collected from the sites and added a reagent packet (Colilert or Enterolert, IDEXX) to the bottle. Each reagent packet contained a species (or genus) specific formulation of nutrients that would initiate growth, which could, then, be used to quantify concentration of bacteria in a sample. For sand samples, students weighed and transferred a known quantity of sand into a sample container, and eluted bacteria from the sand by adding a saline buffer to the container and shaking it in a manner similar to that described by Boehm et al [24]. This standardised protocol essentially mobilises bacteria into the buffer, which can, then, be mixed with the IDEXX reagent packet and induced to grow. After an overnight incubation step, university students were able to complete the analysis in laboratory and determine bacterial density for all samples.

Session 3: The following week, university students shared sample results and assisted middle school students with data analysis and poster-making. Middle school students worked with university students to graph the data their group had obtained. In some cases, data were shared among groups for related research questions so data could be analysed together. Students also chose photographs from the field site and sample-processing events, wrote the text to put into the PowerPoint slides, and decided the format and layout of the information and data on the poster. Each group created one PowerPoint slide to be printed as a large (2' by 3' or 60.69 cm x 91.44 cm) poster (Figure 1).

Session 4: Middle school students visited UCLA to present results from the field day. A typical schedule for the visit was as follows: 9.30-10.30: Panel on college life. University students served as the panel and middle school students were free to ask questions on any topics, including pathways to college or what life was like as a college student.

Even though the students had been getting to know each other informally all quarter, this provided an opportunity for a lively discussion guided by the interests of the middle school students. 10.30-11.30: Students toured campus together in their small groups. Tours were tailored to the students' interests, with locations including the dormitories, Powell library and research laboratories. 11.30-12.00: Lunch. 12.00-13.00: Poster session at which the middle school students were able to present their findings to a broad range of university faculty and students from many departments.

Post-activity letter writing: Middle school students wrote letters to the mayor about the importance of coastal water quality and walked the letters to City Hall. Both the letter writing and the response from the mayor came well after the end of the course; thus, any potential benefit from this engagement activity would not be reflected in the course surveys.

Survey Questions

Pre- and post-activity surveys were developed and administered for two years of the programme. Undergraduate students were asked several questions about career choices and their opinions of politics, and middle school students were asked their opinions about science and politics (Table 2).

Table 2: Survey question topics for undergraduates and middle school students.

Career	Politics	Science
Students ranked their interest in the following careers: Engineer - Private Engineer - Public K-12 Teacher Professor Management	Students were asked to agree or disagree about aspects of themselves: Well-qualified to participate in politics Good understanding political issues Could be good public official Better informed about politics than others Public officials do not care what I think People like me have no say in government Politics too complicated to understand	Students were asked to agree or disagree about aspects of themselves: Interested in science Believe science is important for all Clean drinking water is important Clean recreational water is important Interested in the local environment Interested in global environmental issues

Statistics

Survey answers from undergraduate students regarding career choices were transformed into numbers on a scale from 1 to 5 for the purposes of data analyses. Differences between pre- and post-activity answers were determined through a Repeated Measures ANOVA with a Greenhouse Geisser correction using SPSS statistical software (SPSS Inc., Chicago, Illinois).

RESULTS AND ASSESSMENT OF THE SL PROGRAMME

Quantitative Evidence: Pre- and Post- Survey Results

Pre- and post-activity survey results were examined in each year to assess the impact of the SL component on the students' opinions of various scientific and political issues, as well as impacts on their visions of future careers (Figure 3). Of the 12 questions asked of undergraduate students in both years, four were statistically significantly different ($p < 0.1$), two in each year. Undergraduate students in 2008 felt that they were better informed about politics and government than most ($p = 0.056$) and that they had more say in the government ($p = 0.069$) after the SL activity. In 2009, undergraduate ratings ($n = 10$) for both their likelihood to go into management ($F(1,9) = 6$, $p = 0.037$) and their feeling that politics was very complicated ($F(1,9) = 9$, $p = 0.015$) increased significantly from the initial to the final survey. It is interesting to note that undergraduate students both felt that they were now better informed than their peers about politics and that politics was more complicated after the SL activity. Often a better understanding of material leads to a feeling that it is more complicated because more of the nuances become visible to a better-informed party. For all four of these categories, the same trends were observed across both years, although they were only statistically significant in the one discussed above.

Interestingly, although trends were consistent across years for the undergraduate students, that was not the case for middle school students. In 2008, middle school student pre- and post-activity survey results ($n = 20$) were analysed, and ratings for both the importance of science ($p = 0.054$) and for interest in the local environment ($p = 0.072$) had increased significantly from the initial to the final survey. In 2008, middle school students felt they were better informed about politics ($p = 0.058$) and thought that public officials cared more ($p = 0.061$) after the session. In 2009, middle school students ($n = 25$) felt that politics was less complicated after completing this activity ($p = 0.076$).

Qualitative Evidence - Excerpts from Undergraduate Open-Ended Survey Questions 2009

In order to glean a qualitative understanding of the effects of this project on the students, surveys were read through to assess overall student opinions. Although middle-school students were also asked about future career choices and what, if anything, had changed in their answers, no visible trends emerged in reading through career choices. Additionally, none of the middle-school students addressed the question about changes through the course of the SL experience. The following statements are about the undergraduate responses to the surveys in 2008 and 2009.

Overall, students had a positive view of the course and the SL portion. Among other questions, students were asked to read through their pre-survey answers after answering the post-survey and analyse their answers. If anything had changed, they were asked what had changed and what, if anything, they did in the class they thought might have changed their answers. Students who responded to that question on the survey were very pleased with the results of the laboratory class, regardless of whether their answers had changed over the course of the class or not. One undergraduate wrote, *nothing changed in my answers* [to the survey questions]*, but the lab class was a very rewarding experience and I would do something like it again, even if there was no school credit.* In some cases, this course helped students refine their career goals from broadly within the environmental sector to more specifically environmental engineering or water resources.

The reflection question in the post-survey also offered undergraduates a chance to think about what had changed in their survey answers after participation in SL, and why they thought their answers might have changed. One student wrote: *My likelihood of being a K-12 teacher increased slightly. Maybe the fact that we worked with students and my interaction with them helped change this. For some students, this course also fostered an understanding and appreciation of the course material because they learned it in an application that was interesting and relevant to an environmental/public health question.* [After this experience] *I have a new appreciation for microbiology because I see a lot of how the environment is affected by microbiological things.*

Another interesting facet that emerged from looking through the undergraduate pre- and post-surveys was regarding students' intention to become civically engaged. Most undergraduates responded that they intended to be involved in their communities, although a few said no both before and after the SL activity. Undergraduate responses in terms of what they would do reflected their enjoyment of the course. Responses included an increased interest in working with K-12 students from seeing their enthusiasm, a feeling that they understand better how much there is to know about microbiology and water quality, and that working on this project with kids increased their interest in the research and material.

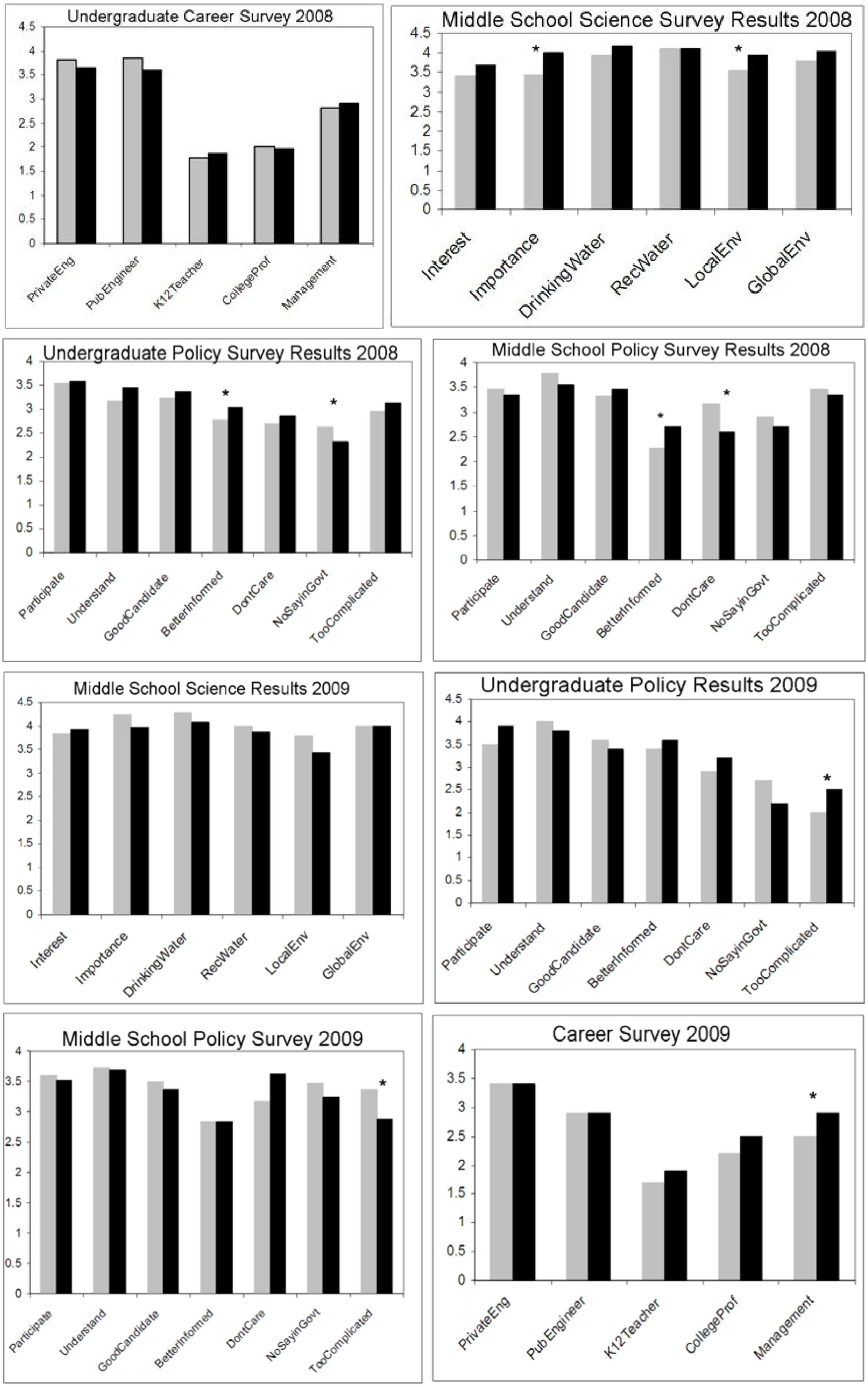

Figure 3: Average results from surveys. (* denotes statistically significant result. Y-axis is average score (out of 5)).

The results in politics were mixed, with some students feeling more informed about politics and others feeling like they were less qualified for politics or public office. This mixed result was likely an artefact of less time spent on the political outreach portion of the SL project than the scientific research portion. Nonetheless, that even a few students felt more empowered to engage in local politics and more informed even with such a small element of policy-oriented activity is a very promising base on which to develop further this portion of the SL component. It can also be observed that participating in a service learning/community outreach project helped some students clarify and refine the ways in which they wanted to be a civically engaged citizen in their lives (see Table 3).

Table 3: First and last week responses to: What kinds of things will you do as a civically engaged citizen? If yes, what kinds of things will you do as a civically engaged citizen?

Student	First Week	Last Week
1	Strive to make socially and environmentally responsible choices in both my personal and professional lives.	Try to stay informed on political/social issues. Take action when I can, volunteer to help.
2	Help the underprivileged (SIC)/those in need.	Help out in the community and vote.
3	I will likely be working with members/leaders of cities to help build infrastructure.	Mentor students and be aware of societal concerns as an engineer.
4	Vote, work on community projects, be involved.	Get involved and work on community projects that benefit everyone, especially environmentally.
5	Health care.	I would help the underserved community of LA or whichever city I end up residing in.

CONCLUSIONS

This work shows that a SL programme can be added as an optional component to a traditionally lecture-based class and that even a modest addition resulted in beneficial impacts on both undergraduates and middle school students. UCLA students were able to gain mentoring experience and develop relationships with middle school students through repeated sessions working in the same small groups.

Hypothesis-driven environmental research was the focal point of the work and students gained experience in analysing and presenting results. This relatively small intervention was able to show statistically significant gains in the level of interest in science of participating middle school students.

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BIOGRAPHIES

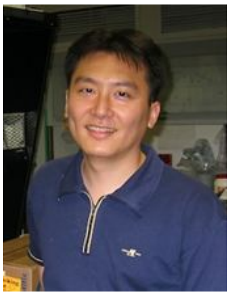
Kathryn B. Mika received a Double BA in Environmental Earth Science, and Spanish Language and Literature at the University of California, Berkeley, in 2004. She received her MS in Civil and Environmental Engineering at the University of California, Los Angeles (UCLA) in 2008 and is currently working on her PhD in Civil and Environmental Engineering under the advisement of Dr Jennifer A. Jay. She participated in the Student Career Experience Program in 2009, working for four months with the Environmental Protection Agency in Washington, D.C. She would like to pursue a career in which she can keep working in the fields of education, science and policy.

Tiffany Y. Lin has a BS in Chemical Engineering, MS in Environmental Engineering, and is currently pursuing her PhD in Environmental Engineering at UCLA. Her graduate work focuses on arsenic contamination in Bangladesh groundwater.

Marcia Ferreira received her BS degree in Environmental Geology and Mathematics from the California State University, Northridge (CSUN), in 2007, and the MS degree in Civil (Environmental) Engineering from the University of California, Los Angeles (UCLA), in 2009. She is currently a PhD candidate in the Civil and Environmental Engineering Department at UCLA. She received the NSF Graduate Research Fellowship (2009-2012) and investigated the presence of mercury in sediments around a drinking water reservoir after a major wildfire. She is currently studying the performance of treatment units for storm water runoff pollutants.

Jessica Lacson recently earned her BS in Civil and Environmental Engineering from UCLA. She has assisted on research pertaining to the bioaccumulation of mercury in aquatic ecosystems, as well as arsenic mobilisation in Bangladesh soils and pond liners. She has recently joined the 2012 corps of Teach for America and is currently teaching high school mathematics in Oklahoma.

Dr Christine Lee has extensive research experience in rapid, field-portable detection methods for assessing pathogen surrogates in the context of water quality and pollution, as well as bioterrorism and sterilisation efficacy. Her postdoctoral work at the Jet Propulsion Laboratory (JPL) also includes understanding microbial communities in extreme environments such as those in Mt Kilimanjaro glaciers and Antarctic Dry Valley soil towards astrobiology goals. She has conducted field-work in Bangladesh, Tanzania, Mexico and Antarctica. Christine actively participated in the UCLA Chapter of Engineers without Borders for five years. She received the Switzer Foundation Environmental Leaders Fellowship in 2008-09 and co-authored a funded proposal for the EPA People, Planet and Prosperity Student Design Competition in 2009-10. Christine recently accepted an opportunity to work at NASA headquarters in Washington, D.C. as a AAAS Science and Technology Policy Fellow.



Dr Chu-Ching Lin is an Assistant Professor in the Institute of Environmental Engineering at the National Central University in Taiwan, teaching graduate courses in Environmental Ecology, Environmental Microbiology, Fate and Transport of Contaminants in the Environment, and Biological Processes of Environmental Engineering. His current research focuses on improving the understanding of microbial-mediated processes involved with the fate of contaminants in the environment and biomass energy production, including biogeochemical processes of heavy metals in aquatic and terrestrial systems, optimisation of biogas production from agricultural and municipal solid waste, as well as biotransformation of endocrine disrupting chemicals (e.g. pharmaceuticals and personal care products).

Dr Kathy O'Byrne has been the Director of the UCLA Center for Community Learning for the last 11 years, supporting academic courses and programmes that connect the university with community partners throughout Los Angeles. She was previously a tenured Professor at Cal State Fullerton, where she worked in campus-wide administration as the Director of Freshmen Programs and Director of Service Learning. Dr O'Byrne graduated from Vassar College, earned a Masters degree in Counselling Psychology from Arizona State University and a PhD from the University of Southern California. As a licensed clinical psychologist, she maintained a private practice for many years and has over 30 years of experience working with non-profit organisations.

Dr William A. Sandoval is an Associate Professor in the Graduate School of Education and Information Studies at UCLA. His research centres on designing learning environments to promote children's scientific argumentation, and studying how such work is influenced by and influences children's understanding of the nature of scientific work.

Vanessa Thulsiraj is a PhD candidate conducting her doctoral research in Dr Jay's laboratory at the University of California Los Angeles (UCLA). Her research has focused on fecal source tracking utilising molecular and rapid methods in urban watersheds and beach areas within Southern California and Tijuana, Mexico. She graduated from the University of California, Irvine, in 2007 with a BS in Environmental Engineering and obtained her MS in the Civil and Environmental Engineering Department at the University of California Los Angeles, in 2010.

Jennifer A. Jay received her BS, MS and PhD in the Civil and Environmental Engineering Department at Massachusetts Institute of Technology (MIT), and has been on the faculty in the Civil and Environmental Engineering Department at the University of California, Los Angeles (UCLA) for the last ten years. She teaches courses in aquatic chemistry, environmental microbiology, chemical fate and transport, and a service-learning course in which UCLA undergraduates conduct community-based environmental research with local 7th graders. She currently directs an active research programme related to mercury and arsenic biogeochemistry, and microbial contamination of water and sand at local beaches. In 2003, she received the Presidential Early Career Award in Science and Engineering (PECASE) to study mercury cycling in environmental biofilms. She was recently recognised as a Carnegie Foundation Faculty Fellow for Service Learning for Political Engagement, and also received the Northrop Grumman Award for Excellence in Teaching.