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AC 2009-610: TRANSDISCIPLINARY GREEN ENGINEERING EDUCATION AT SAN JOSE STATE UNIVERSITY

Belle Wei, San Jose State University

Dr. Belle Wei was appointed dean of the Charles W. Davidson College of Engineering at SJSU in 2002. With nearly 5,000 students, the college is the largest provider of engineers to Silicon Valley companies and has consistently received top ranking among the nation's engineering schools offering undergraduate and master's-level programs. Dean Wei has led the college in developing its vision to educate new engineers, who are technically excellent, broadly educated, and socially responsible.

Patricia Backer, San Jose State University

Dr. Patricia Backer is Director of General Engineering in the College of Engineering at SJSU where she is responsible for coordinating the College's efforts in green engineering. As the co-author of the book *Contemporary Technology* she has conducted research for the past ten years about the interactions of technology and society.

Transdisciplinary Green Engineering Education at San José State University

Abstract

Climate change is a pressing issue for the world today. There are an increasing number of technological by-products posing a threat to the stability and quality of the world environment. According to the United Nations' Intergovernmental Panel on Climate Change (IPCC), global warming appears to be accelerating, resulting in higher increases in global temperature and higher rises in the sea level. To effectively address this problem, there is a need for transdisciplinary, transnational approaches, reflecting the complexity of the problem and the interdependence of people's lives around the world. Consequently, the Davidson College of Engineering at San José State University (SJSU) has programmatically encouraged and supported the development of new green engineering curriculum and research, collaborating with Silicon Valley companies, many of which are at the forefront of green technologies. At the university level, the college has spearheaded a university-wide curriculum that brings together students from all seven colleges of the university to develop a deep understanding of the different aspects of climate change solutions: economic, political, moral, aesthetic, and technological. Furthermore, to augment student learning with a global perspective, the college sponsored the production of a "global green" documentary that showcases the collaborative efforts of people in both the U.S. and China. These efforts, among other initiatives, highlight a systematic theme of sustainable and green engineering at SJSU.

1. Introduction

Climate change has emerged as the biggest problem facing humanity in the 21st century. Climate change caused by fossil fuel use has damaged and, if unabated, will continue to damage the environment upon which human beings depend for sustaining life. Compounding this problem is the rapidly growing demand for fossil fuel, brought upon by an expanding global economy and a growing world population.

Given the dire consequences of climate change, the Davidson College of Engineering (CoE) at SJSU has identified green and sustainability engineering as the overarching theme for focused development. This theme exemplifies the college's vision of educating engineers to improve the world through innovative applications of engineering knowledge and skills. In other words, the College emphasizes the development of innovative multidisciplinary solutions to pressing human problems, and fosters students' moral commitment to use their education in a way that benefits not only themselves, but also the society and the world.

Besides exemplifying the college's vision, the field of green and sustainability engineering promises career opportunities for engineering graduates. For instance, the three largest cities in the San Francisco-San Jose Metropolitan area have recently established the Climate Change Compact¹. The compact has ten goals that include reducing the gasoline usage by 3% from 2008 to 2013 as well as increasing the number of electric cars. Another goal is to place 20,000 new graduates in green technology jobs. Given these goals, it is important that SJSU contribute not

only research and development but also well-educated graduates to advance the cause of this important endeavor.

At the state level in California, energy research will be accelerated by state law AB 32. AB 32 mandates aggressive standards for emissions in California by 2020. Economists have found that, in order to meet AB 32's goals, businesses will generate tens of thousands of new jobs for California². According to a World Wide Fund for Nature study³, California is expected to gain over 140,000 new clean tech jobs by 2020. Along with new jobs, Californian industries will invest heavily in research and development efforts in renewable energy.

When it comes to developing comprehensive solutions to the climate change problem, we are mindful of the fact that they extend beyond the boundaries of a single academic discipline. This requires a systems approach that reflects the interactions between the human and the natural world. In this systems approach, technology plays a central role in determining how we harness and use energy resources with the goal of meeting human needs. However, technology development and application does not exist within a vacuum. It is driven by economic interests and public policies that are shaped by social, economic, and political forces. That is, the solution is transdisciplinary, cross-cutting scientific, engineering, and humanistic disciplines. It is also transnational, reflecting the global nature of climate change.

Given this transdisciplinary systems approach, the college has programmatically encouraged and supported the development of new green engineering curriculum and projects inside the college, and collaborated with Silicon Valley companies, many of which are at the forefront of green technologies. This is described in Section 2. The college has spearheaded a university-wide curriculum that brings together faculty and students from all seven colleges of the university in developing project-based interdisciplinary solutions; this is described in Section 3. Furthermore, to underscore the need for a transnational approach, the college has led the production of a global green documentary, showcasing the collaborative efforts of people in both the U.S. and China. The documentary, described in Section 4, will be used to educate students on various facets of climate change problems and solutions. The final section, Section 5, describes the college's ongoing efforts to substantiate its transdisciplinary and transnational approach to climate change, working with the SJSU campus community and the Silicon Valley community and beyond.

2. Green Engineering Curriculum and Research

Green engineering cross-cuts all engineering disciplines. It covers not only discipline-specific but also interdisciplinary courses and projects. The discipline-specific courses at SJSU include mechanical engineering courses in Solar Energy, Fuel Cell Energy, and Alternative and Renewable Energy; civil engineering courses in Environmental Engineering; and technology courses in Green Manufacturing. We also offer an interdisciplinary curriculum path, a green engineering minor degree.

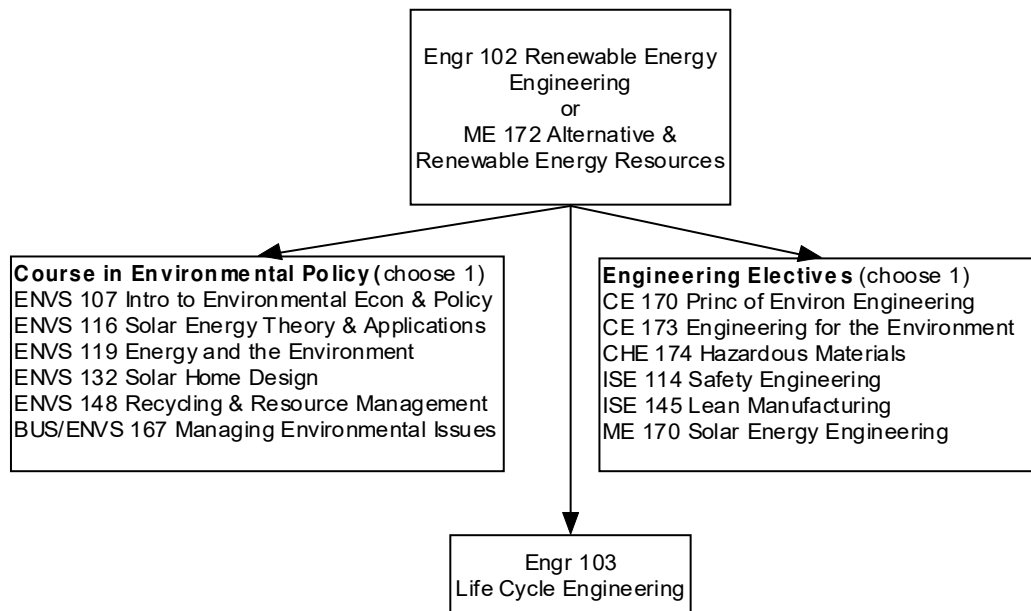
2.1 Green Engineering Minor Degree

Over the past decade, several green and sustainable engineering programs have been established in the United States. These include the University of Texas at El Paso^{4 5}, Rowan University^{6 7},

Carnegie Mellon University⁸, Virginia Tech⁹, and Rochester Institute of Technology¹⁰. In our curriculum development at SJSU, we reviewed these programs and adapted portions of them for our own new multidisciplinary green engineering minor program, which was started in Fall 2008. The key learning outcomes of the green engineering minor are to: understand the energy generation from renewable energy resources such as sun, biofuels, wind power, and wave power; understand energy conversion and storage devices such as rechargeable batteries and fuel cells; analyze the economic and environmental impact of renewable technologies; promote student research projects that apply new sustainable and environmentally sound technologies and methods to real world problems; and use life cycle thinking in engineering activities.

The Green Engineering minor is housed in the General Engineering department at SJSU. The green engineering minor contains four, three-unit classes (see Figure 2, a sample road map for this minor). Students may take their green elective and environmental studies or business class at any time in the sequence. Engr 102 (Renewable Energy Engineering) or ME 172 (Alternative and Renewable Energy Sources) must be taken before Engr 103 (Life Cycle Engineering). Engr 103 was developed based upon a similar course at Virginia Tech. In the first two semesters, over 35 students from five engineering disciplines have enrolled in the green engineering minor courses.

Figure 2. Courses in the Green Engineering Minor, SJSU



2.2 Research in Green Engineering

The development of research is a critical part of the College’s strategy to encourage sustainability in engineering. Since 2003, the College has supported faculty research and curricular efforts through an internal Engineering Faculty Development Grants program. In Fall 2007, a Special Call for Proposals was sent to fund projects related to Green and Sustainable Engineering. The following four projects were funded:

- Dr. Yasser Dessouky, Industrial & Systems Engineering—to develop an approach to calculating the carbon footprint of the supply chain for the electronics industry.
- Dr. Peter Reischl, Electrical Engineering—to design a showcase demonstration project of smart meters as part of the smart grids.
- Dr. Lili He, Electrical Engineering—to develop a proof of concept for a photovoltaic system that surpasses existing systems in efficiency and cost.
- Dr. Jinny Rhee and Mr. Jim Mokri, Mechanical Engineering—for the design and implementation of the first generation prototype of a cogenerating photovoltaic and thermal solar collector.

In addition to the research funded by our special grant program in green engineering, SJSU Engineering faculty have made progress in the following green engineering research.

- The extraction of bio-oils and transesterification of the bio-oils to bio-diesel from various biomass sources (oil seeds, microalgae, and yeast) using a novel green solvent technology. This research is being conducted by Dr. Greg Young while he is on sabbatical at the University of Hawaii; it is supported by two industrial sponsors, LiveFuels and BioEcoTek.
- A team of 77 mechanical and electrical engineering students designed and built a Zero Emission (ZEM) vehicle using a combination of solar power, electricity, and human power. This project involved two vehicles: the mini-ZEM vehicle and the full-sized ZEM vehicle. The ZEM vehicle design won the first-place in the national idea-to-product competition in 2007. Three different faculty members from SJSU's College of Engineering (CoE) are involved in the project: Dr. Tai-Ran Hsu and Dr. Raymond Yee from Mechanical Engineering and Dr. Thuy Le from Electrical Engineering. This project is supported by Sun Power Corporation and Clean Power Battery Technologies.
- Dr. Jinny Rhee is working on a solar icemaker in a collaborative effort with the College of Business at SJSU. The solar icemaker is an electricity-free, passive device that is capable of freezing water into ice. This project is supported by Hewlett-Packard.

3. University-wide Climate Solutions Initiative

The Climate Solutions Initiative (CSI)¹¹ involves a truly transdisciplinary educational approach. This project was an effort between the CoE, five other colleges at SJSU and the Institute for Social Responsibility, Education and Ethics. The purpose of the CSI course is threefold: (i) to prepare students for the ethical challenges that they will face in their lives and careers, (ii) to expose students to the different paradigms used by professionals from other fields, and (iii) to engage students with faculty who are at the forefront of their respective disciplines. The CSI curriculum project was piloted in Fall 2008. Six SJSU faculty members, representing the Colleges of Business, Science, Engineering, Applied Sciences & Arts, Social Sciences, and Humanities & the Arts, met with hand-picked student teams. These students came from seventeen majors across campus in six colleges (Table 1).

The students in the CSI course presented their projects at an event in December 2008. A one-hour poster presentation was followed by presentations from each of the six groups in the class.

The student projects were judged by a team of four industry leaders. The assessment of the pilot class indicated that this course had the following strengths:

- The projects from the student teams demonstrated an in-depth and interdisciplinary analysis of climate change issues.
- The students indicated that they collaborated well within their groups.
- The faculty reported that they had a high level of rapport with the students and other faculty leaders.

Table 1. Distribution of Students by College in Fall 2008 CSI course

College	Number of Students
Business	10
Applied Sciences and Arts	4
Engineering	5
Humanities & the Arts	4
Science	1
Social Sciences	4

The two winning projects exemplified the transdisciplinary nature of this course. The first place team project, *Through You, Through Food*, was led by a professor from Meteorology, Dr. Eugene Cordero¹². This project had two parts: an analysis of the carbon footprint of a typical SJSU student and a social marketing campaign designed to educate SJSU students about the connections between food and global warming. The team’s analysis revealed that each SJSU student was responsible for 16,000 lb of CO₂ emissions annually and that 28 percent of that was due to food consumption. This project developed a low cost and practical model to encourage university students to reduce their carbon footprint.

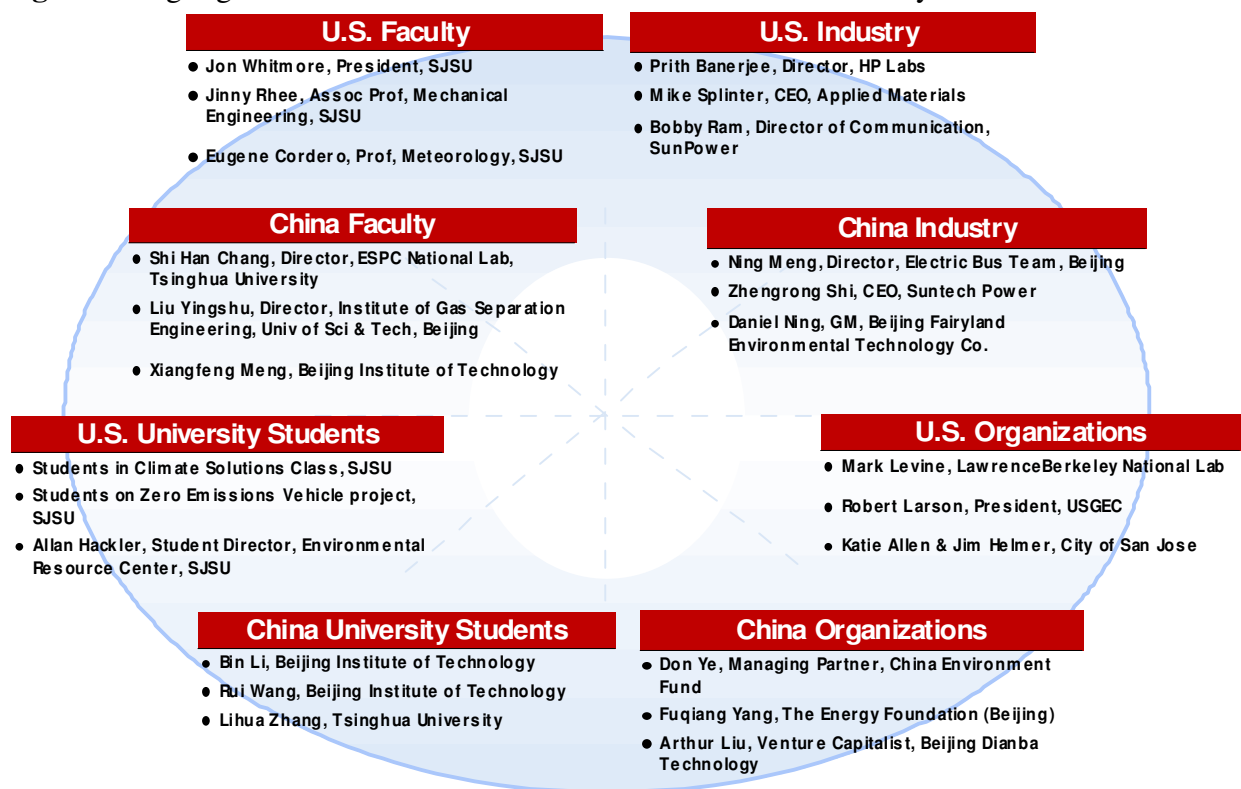
The second place team project, *Grow Up, Grow Smart: Sustainable Development Using Vertical Farms*, was led by a professor in Political Science, Dr. Lawrence Quill. In their research, they found that over 50% of students (nationally)¹³ and approximately 37% of students at San Jose State University¹⁴ are suffering from health issues that are related to their poor eating habits. The student team developed a comprehensive plan to establish rooftop farms atop the buildings of the SJSU campus in order to provide students with cheap, campus-grown food. This project could lower the carbon footprint of SJSU while helping to provide healthier, lower cost food choices for students and staff.

Based upon the CSI pilot course, we initiated a new six-unit Climate Solution Initiative (CSI) course to be offered in Fall 2009. The CSI course fulfills the requirements of two different areas in the General Education program at SJSU: Area R (Earth and the Environment) and Area V (Culture, Civilization & Global Understanding). This new CSI course is cross-listed with all seven colleges within the university. The class is structured with large briefing sections and smaller discussion groups with faculty leaders. Students work in teams to develop solutions that address climate change problems. We have included embedded assessment into the CSI course so that we can continually assess this course each semester it is offered.

4. Global Green Documentary

To effectively address the climate change problem requires concerted efforts of people and governments around the world. To this end, the college sponsored a documentary, “Global Green,” with the target audience of college students in the U.S. and China. The documentary was produced by Prof. Robert Gliner of Sociology, who has extensive experience and a strong track record in documentary film making. The Global Green documentary aims to mobilize college students in the U.S. and China, the world’s two biggest energy users, to develop climate change solutions. The documentary will inspire them to create change by showcasing the incipient joint efforts of people in both countries. It is intended to be shown on U.S. and Chinese PBS stations, as well as on the web and in college classrooms.

Figure 3. Highlights of Interviewees for the Global Green Documentary



The documentary centers on the activities of various players in the U.S.-China Green Energy Council, SJSU, and Tsinghua University, and will focus on the geographical areas of Silicon Valley, Shanghai, and Beijing. The players represent a broad range of fields, reflecting the comprehensive nature of climate change solutions: business, public policy, community engagement, and education. They include technologists who develop renewable energy sources as well as the efficient use of energy, business people who foresee new business opportunities, political leaders who create policies to nurture the development of solutions, community leaders and citizens who are concerned about the future of their community, educators who see developing climate change solutions as a moral imperative, and college students who realize the disastrous impact of climate change on their lives.

For this documentary, we have interviewed numerous faculty and students from institutions in the United States and China (see Figure 3). The documentary will be distributed in Fall 2009.

5. The Future

Developing solutions to address the problems of climate change and renewable energies has become a moral, economic, and global imperative. A problem-focused approach breaks down disciplinary boundaries and provides students a unifying framework for learning scientific and humanistic disciplines in a coherent setting. In particular, students gain scientific knowledge by understanding how human activities contribute to generating the carbon footprint, and how carbon dioxide or green house gases contribute to climate change. The reason why climate change is a problem is fundamentally an ethical issue, that is, whether it is ethical for the activities of one group of people to result in hardships for different groups at later times and in different places. When it comes to developing solutions, students need to understand the social, economic, and political spheres of human society. This understanding is generally in the realm of social sciences and one of these changes is technological, i.e. the development and use of new technologies. With the above framework, we have played a leadership role in bringing to fruition the multidisciplinary curriculum in climate change solutions at the SJSU campus, as well as educational and research projects in Silicon Valley and globally.

As for engineering education, we have developed green and sustainable engineering curriculum and projects over the past three years. In the future, we will expand our scope to instill sustainability concepts in **all** students in **all** degree programs in the college throughout **each** year of their degree program. We have begun this integration by focusing on two concepts in sustainability: energy conversion and life-cycle engineering. A team of SJSU faculty members have begun to integrate these concepts into our freshmen *Introduction to Engineering* class and our sophomore *Introduction to Materials* class. We will build on this effort and develop a comprehensive blueprint for embedding sustainability throughout the College. By embedding sustainability into all of the different engineering majors at SJSU, we will be able to introduce the concepts in freshmen and sophomore years and reinforce them in more depth and complexity as students take their junior and senior level courses in their majors. After completing an engineering degree at SJSU, students would increase their understanding of (1) environmental issues and the local and global impact of engineering, (2) how to integrate energy conservation and efficiency in their engineering designs and practice, and (3) how to design products focusing on a cradle-to-cradle philosophy that mimics the natural world. As an institution of higher learning that encourages interdisciplinary education and scholarship, SJSU is well poised to be a leader in this area.

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