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Lawrence Quill, *San Jose State University*
Jinny Rhee, *San Jose State University*
Eugene Cordero, *San Jose State University*

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Pilot Implementation of an Interdisciplinary Course on Climate Solutions*

JINNY RHEE
Department of Mechanical and Aerospace Engineering, San José State University, One Washington Square, San José, USA, CA 95192-0087. E-mail: Jinny.Rhee@sjsu.edu

EUGENE C. CORDERO
Department of Meteorology, San José State University, One Washington Square, San José, USA, CA 95192-0104. E-mail: cordero@met.sjsu.edu

LAWRENCE R. QUILL
Department of Political Science, San José State University, One Washington Square, San José, USA, CA 95192-0119. E-mail: Lawrence.Quill@sjsu.edu

A pilot implementation of an experimental interdisciplinary course on climate solutions was undertaken at San José State University in the fall semester of 2008. The course, co-taught by seven faculty members from six colleges, was approved for a general education requirement and was open to upperclass students campus-wide. A course with such a breadth of topics and range of student backgrounds was the first of its kind here. The lessons learned from the pilot effort were assessed from student, faculty, and administrative perspectives. The educational benefits to students from the interdisciplinary format were found to be substantial, in addition to faculty development. However, challenges associated with team-teaching were also encountered and must be overcome for the long-term viability of the course. The experimental course was approved as a permanent course starting in the fall semester of 2009 based on the pilot effort, and plays a role in the College of Engineering's recent initiatives in sustainability in addition to campus-wide general education.

Keywords: team-taught course; project-based learning; multidisciplinary instruction; interdisciplinary instruction

1. MOTIVATION AND BACKGROUND

THE PRESENT NEED for multidisciplinary education for engineers is evident. Sheppard et al. write that 'technical and non-technical issues are inextricably and increasingly linked' [1] in today's world. Berezin [2] describes the proper balance between technical training and a general background in social human knowledge as being the key to avoiding fragmented knowledge in poorly interacting specialties. Borrego and Newswander [3] state that by 'understanding the underlying differences [in viewpoints] and how these can expand possibilities for research, would-be collaborators can learn lessons invaluable to cooperation, communication, and ultimate understanding.' Furthermore, there is evidence to suggest that graduates from professional schools have little idea about the ethical issues they might face in their professional lives beyond a crude appreciation of their profession's codes of conduct, combined with a mixture of ethical relativism and moral intuition. 'Technical virtuosity', notes a recently published study of Stanford Engineering students, 'coexists with a widespread lack of specific knowledge of what is involved in being an ethically and socially responsible engineering professional' [4].

There is a growing body of work describing cross-disciplinary courses in engineering education. Recent efforts to combine engineering and non-technical disciplines include collaborations with humanities and social science; engineering and applied science [5]; design and communication [6]; engineering and entrepreneurship [7, 8]; as well as engineering, business, art, and writing [9]. Multiple efforts to combine multiple engineering disciplines in project-based courses exist, such as architecture, engineering, and construction [10]; civil, mechanical and electrical engineering [11]; and electrical engineering and various other engineering disciplines [12]. Multidisciplinary engineering projects are well-suited for capstone courses [13, 14], as well as integrated design courses throughout the four-year engineering curriculum [15]. In several of these papers, support from their academic institutions and the quality of student mentoring were cited as keys to successful implementation of these courses. Obstacles to successful implementation of multidisciplinary education include fragmentation of disciplinary information, inability to digest the shear volume of existing information, and lack of access to relevant information [16].

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Energy and sustainability are topics that are particularly well-suited to interdisciplinary teaching approaches, and there is a pressing societal need for graduates with knowledge of these areas [17]. In a survey administered to universities with an environmental engineering program and to potential employers of its graduates, results indicated the importance of combining societal aspects such as law, economics, psychology, ethics, and social management skills along with engineering and science. Results also highlighted the importance of interpersonal skills such as teamwork and communication [18]. Today, there are many multidisciplinary courses open to engineering and technology majors offered in this area by various universities that cover topics ranging from renewable energy, sustainability in mining, and design of green buildings [19–24].

2. PILOT IMPLEMENTATION OF CLIMATE SOLUTIONS COURSE

At San José State University (SJSU), a pilot implementation of an experimental general education course involving seven faculty members from six colleges, open to the entire campus community, was undertaken in the fall semester of 2008. The overarching theme of the class was Climate Solutions. A course with such a breadth of topics and range of student backgrounds was the first of its kind here at SJSU. Borrego and Newswander [3] distinguish between so-called 'multidisciplinary' efforts, where team members contribute expertise to the final product without fully understanding all the parts, and so-called 'interdisciplinary' efforts, where all individuals contribute towards a fully integrated common solution. It was our hope that such a course would produce 'interdisciplinary' outcomes from both faculty and student perspectives.

The pilot course attracted twenty-eight students spanning seventeen majors from six colleges, and was approved for fulfilling an upper division general education requirement covering Culture, Civilization, and Global Understanding. Upperclass undergraduates and graduate students were eligible to sign up. The course was conceived by the Institute for Social Responsibility, Education, and Ethics (ISREE) at SJSU and funded primarily by the College of Engineering, with further support from all involved colleges. The lecture topics covered by the colleges and departments are listed as follows:

- Humanities and Arts (Philosophy): Ethical issues and global concerns;
- Science (Meteorology): Global warming science;
- Engineering (Mechanical Engineering): Renewable energy and its use in the world;
- Social Sciences (Political Science): Political dimensions of global climate change;
- Business (Organization/Management): Green entrepreneurship and sustainable business;
- Applied Science and Arts (Hospitality): Eco-tourism;
- Humanities and Arts (Foreign Languages): Environmental campaigns in American history.

Eight weeks of lectures (half a semester) on the above topics were followed by a midterm examination. The second half of the course was devoted to group student projects led by a faculty mentor. The faculty mentors were not assigned any students from their own colleges. The final projects required a poster session, oral presentation, and final report, and were judged by a panel of outside experts on aspects of climate change. The goal of the group project was to design an innovative solution addressing climate change with the winning group, as judged by the outside panel, receiving a prize. Project topics reflected the interests of the faculty and included: the impact of food choices on the environment, vertical farms in communities, evaluation of barren land use, bicycling solutions in urban areas, sustainable tourism, and alternative solutions to bottled water.

3. ASSESSMENT

After the conclusion of the pilot course, data for course assessment were gathered from three constituents: the students, the faculty team, and the deans of the participating colleges. Informed consent and confidentiality of the participants were implemented, and this assessment qualified for an exemption from full review by the Institutional Review Board (IRB). The online student surveys asked for general background information, their opinions on the course structure and logistics, and information on their attitudes, beliefs, and instructional preferences. The online data referred to in this work was collected using 'asset', a web-based survey system created by Bert G. Wachsmuth at Seton Hall University. The data from the faculty and deans were gathered in the form of interviews. The faculty interview asked the participating instructors about their opinions on the course structure and logistics, their perception of the students' reactions, and any benefits they have received from the interdisciplinary effort. The faculty interview questions were adapted from a validated instrument for an interdisciplinary team-taught course found on the website for the Online Evaluation Resource Library (http://oerl.sri.com). Lastly, the deans were asked about the administrative perspective on interdisciplinary instruction.

The questions that we sought to answer with our assessment are the following:

- How successful was the integration of such a broad range of subjects?
- What were the key factors to positive student outcomes?
- What was the role of competition in the classroom?

- What were the challenges found in the pilot effort?
- What were the benefits of the interdisciplinary approach, from an education, faculty development, and university standpoint?

4. RESULTS

Twenty-one out of twenty-seven responses (one student withdrew from the course prior to the end of the semester) to the student survey were successfully completed for this study. A representative sample was obtained; responses were received from students in all six colleges, as well as from all six section instructors (Dr. Hadreas did not lead a section, the remaining instructors each supervised a section of 4–5 students). All seven faculty instructors and five out of six deans from the participating colleges were interviewed by the authors. The results of our assessment are reported in this section.

4.1 Relevance of lecture topics

One of the distinguishing features of our interdisciplinary effort is the broad range of topics incorporated. The students and faculty were asked to rate the relevance of each subject covered for the topic of climate solutions. The students' responses are graphed in Fig. 1.

On average, all of the students in the class rated all of the seven topics as relevant and essential. The standard deviation in the responses varied from subject to subject and indicates the spread in the results. Although not statistically significant due to small sample sizes, it is interesting to note two trends: (1) students from the college of the lecturer rated the subject as more relevant than the class average except in the cases of 'Eco-tourism' and 'History'; and (2) the engineering students rated the technical lectures, 'Climate Science' and 'Renewables' as more relevant than the other subjects. These trends in our pilot effort lend support to the idea that disciplinary training predisposes us to value familiar topics. It would be interesting to see if these trends persist in a bigger population.

Faculty also rated the different topics highly, with all agreeing that 'Climate Science' and 'Renewables' were essential. Naturally, there were some faculty who rated some of the lectures higher than others, but overall, there was a consensus that the course topics and presentations were well-presented, interesting, and relevant. One common thread was the value and benefit of the multiple perspectives, and the role this had both in the lectures and in the projects. One faculty member suggested that students got more out of the class than they could have ever expected, and attributed that to the unique convergence of perspectives on the subject of climate change. In fact, most of the faculty commented on how much they enjoyed hearing different perspectives and how novel this experience was.

We also asked students and faculty if there were any other topics that should be considered for a class on climate solutions. The student responses spanned a range of topics such as nuclear power, legal and regulatory structures, and education in sustainability, with no recurrence of any particular answer. Faculty also suggested additional topics such as climate policy, urban studies, water resources, art and design, but also agreed that this obviously depends on the background of the participating instructors.

In summary, the students and faculty see value

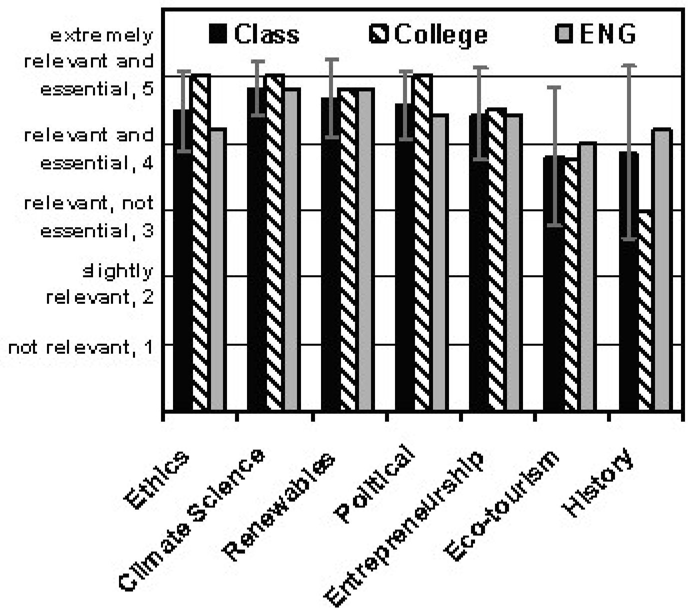

Fig. 1. Student evaluation of relevance of lecture topics to climate solutions. Average ratings are compared for (a) entire class, (b) students from college of lecturer, and (c) engineering students. Standard deviations for class averages are indicated by error bars.

to including a broad and diverse range of topics in a single course on climate solutions. There could be room to adapt the topics to suit the specialties of a given faculty team and/or rotate in some relevant but not essential topics. Generally speaking, however, the student and faculty consensus seems to be that the specific broad range of topics covered in the pilot was a positive and essential feature of this course.

4.2 Correlations to positive student outcomes

Based on the data gathered from the student surveys, there were two primary factors that strongly correlated to a student's reported increased confidence in discussing the course material and overall satisfaction with the course: (1) the section instructor rating, and (2) team dynamics. Other possible factors examined included the students' college, GPA, and motivation for taking class (GE requirement, personal interest, or both); however, there were no strong differences between the resulting subgroups of students when distinguished along these lines. The three combinations of instructor rating and team dynamics that were identified in the pilot are further described below:

High instructor rating, good team dynamics: This subset of students rated their section instructor as 'Excellent' and described their team dynamics as 'All team members worked together towards a common goal.' One of the students from this subset remarked that 'our group went beyond working together to allowing each member to teach the others about their area of expertise.' 73% of these students rated the course as 'One of the best I have ever taken', and the remaining 27% rated it 'Better than average.' As shown in Fig. 2, this subgroup rated their confidence in discussing the course topics generally above the average for the class. It is tentatively concluded that at least some of the student projects in the pilot were truly interdisciplinary as defined by Borrego and Newswander [2], who reported better project outcomes in this case as compared to collaborations where the members work on their own parts without fully understanding the whole.

High instructor rating, suboptimal team dynamics: This subset of students rated their section instructor as 'Excellent', 'Good', or 'Fair' and described their team dynamics either as 'All team members worked on their own parts without fully understanding the whole project' or 'Team members did not work well together,' or 'Other.' Based on the student comments, it appeared these teams either did not get along personally, or had some members that were not motivated on the project. They still had a generally favorable view of the course, however, although not as favorable as the subgroup with a high instructor rating and good team dynamics. Approximately one-third of the subgroup each rated the class as 'One of the best I have ever taken,' 'Better than average,' and 'About average.' As shown in Fig. 2, this subgroup generally rated their confidence in discussing the course topics about the same as the course average.

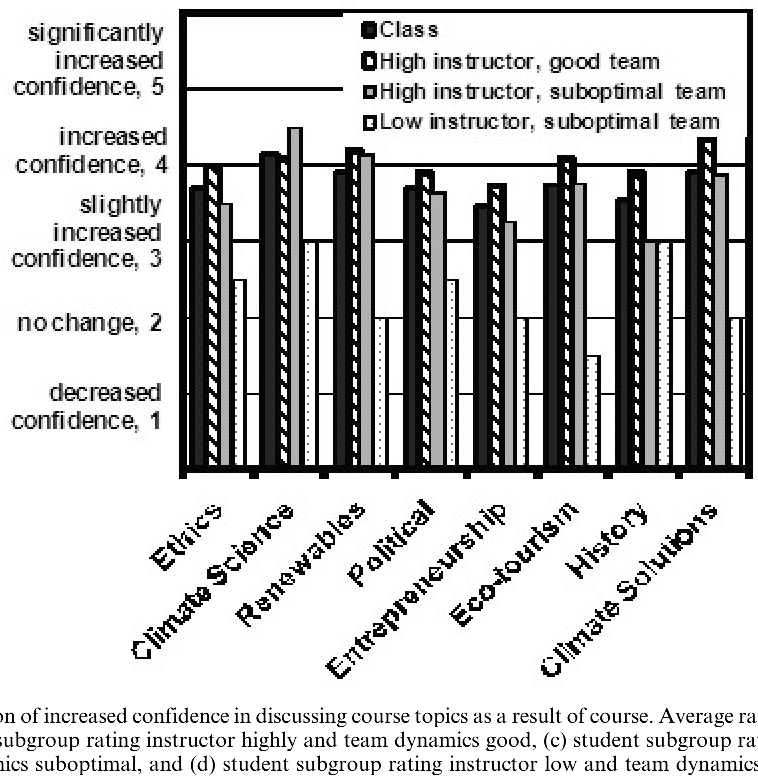

Fig. 2. Student evaluation of increased confidence in discussing course topics as a result of course. Average ratings are compared for (a) entire class, (b) student subgroup rating instructor highly and team dynamics good, (c) student subgroup rating instructor highly and team dynamics suboptimal, and (d) student subgroup rating instructor low and team dynamics suboptimal.

Low instructor rating, suboptimal team dynamics: This subset of students rated their section instructor as 'Poor' and described their team dynamics as 'Team members did not work well together,' or 'Other.' Based on the student comments, it appears that the student project group had substantial personality conflicts, and the instructor was ill-equipped to manage the group and the project. The course was rated by this subgroup as 'One of the worst I have ever taken' or 'Below average,' and they rated their confidence in discussing the course material far below the course averages as shown in Fig. 2. In addition, data was collected asking students to rate the quality of each lecture for internal assessment purposes; although it is not graphed here, this subgroup also rated the quality of the lectures far below the class averages, even though the lectures were delivered by all of the instructors and were somewhat separate from the project. Furthermore, no one in this subgroup indicated any desire to work in this field beyond the course. One student commented that 'I can't really say I learned anything that I could or would use out in the working environment.' It is clear from this outcome that a poor project experience can negatively influence a student's perception of the entire class, as well as desire to learn more about the field.

Summary of correlations: Based on the data, it is clear that the faculty team and the project experience are of paramount importance for the success of this interdisciplinary course. The importance and difficulty in finding an action-oriented faculty team capable of working together for the requisite period of time for a team-taught course is well-supported and corroborated by the prior literature [8]. We hypothesize that the project experience is an integral part of synthesizing and understanding a broad range of topics, and that the faculty team members are capable of having a profound effect in this area.

4.3 Role of competition

The popularity of competition in the classroom environment was mixed from student and faculty perspectives. 52% of the students rated the competition aspect of the course as 'Excellent' or 'Good'; the remaining 48% rated it 'Fair' or 'Poor'. Not surprisingly, many of the students who rated their instructor 'Excellent' and had good team dynamics did well in the competition and rated it highly. Some of the favorable student comments include: '[The competition] brought the project into real life instead of leaving it in the artificial atmosphere of the classroom,' and 'The competition was a huge motivator and I believe created a greater bond with my teammates.' There were negative ratings of the competition from all subsets of students. Some of the negative comments include: '[It] only motivated the people whose idea was selected. Other people do even worse because the topic is not what they want,' and 'The competition aspect made other groups secretive about their work and made the project more isolated than motivated.' The administration of the competition was commented on by some students. One student wrote, 'I think the guidelines for the competition were not clear and therefore the project selection for the competition was skewed.' Lastly, multiple students expressed variations of the desire to work on a bigger and more holistic project with a larger fraction of the students and professors, as opposed to smaller competing projects.

Faculty also offered different views on the role and value of competition in the course. While some thought it did motivate their students and felt it was a useful component to the course, others felt it discouraged some of the groups from communicating and that it didn't help all students engage. The other comment was that the final presentation was probably motivation enough for most students, as they didn't want to embarrass themselves in front of the other faculty and peers. Because the final presentations were open to the public and since the judging panel came from outside the university, the feeling that 'we have to perform well' seemed fairly strong in all the student groups.

4.4 Challenges encountered

The difficulties encountered with the interdisciplinary, team-taught format involve consistency, coordination, and administrative challenges. These challenges are detailed as follows.

Non-uniform grading: There were consistent complaints from the students that the grading in the course was not uniform. Each lecture had an associated essay assignment which was graded by the lecturer; the midterm questions in each topic area were also authored by the lecturer. Typical student comments on the essays include: 'Grading was unfair and unclear; grading policies are misaligned with teacher's requirements,' and 'Each instructor had his/her own method for grading and that makes it hard for students to get a good grade.' On the midterm, students remarked, 'Some of the questions on the exams were really easy and some were too in depth,' and 'Midterm was completely unexpected.' Even on the project, one student wrote, 'I liked the idea of showing off our hard work for people interested in climate change, but I thought it was unfair to have people, unfamiliar with the requirements of the project and course, judge our work based on their personal opinion and interests.'

Several faculty members corroborated the need to standardize grading criteria before the next implementation and also to reconsider the grading structure of the course. 'Was the midterm rigorous enough?' and 'Did we expect too much from students?' were examples of the diversity in faculty opinions. One area a few faculty discussed was the student projects and how there seemed to be different levels of achievement.

Challenges for faculty: Other challenging areas were identified by the faculty and ranged from level of student commitment and course design to how the course was administrated. About half the faculty found some aspect of working and managing small groups challenging, especially when one or more students in their group was not engaged in the project. It was also suggested that improvements in how the course was administered were needed. In particular, faculty mentioned that a formal course coordinator would have been helpful in answering student questions and steering various components of the course more smoothly. Finally, a couple of the faculty felt that the lack of particular resources dedicated to the group projects was unfortunate. They asserted that even a small budget could have been very helpful to each of the project teams.

Furthermore, university reward systems tend to be misaligned with such efforts. Two out of the five deans interviewed noted that the requirements for Retention Tenure and Promotion (RTP) tended to discourage experimentation with interdisciplinary teaching/research (in part, due to the pressure to publish in peer reviewed journals within a specific field). Attitudes from older faculty also appear to be more discipline-centric while younger faculty were interested in pursuing projects that cut across traditional disciplinary divides.

Challenges for administration: SJSU is a large public institution with a diverse student population. The deans were cognizant of the costs of developing and supporting interdisciplinary courses without resources such as huge endowments. As one might expect, the number of examples of interdisciplinary (IDP) teaching and research varied across colleges. In some cases, there were relatively few examples of IDP teaching and research while other colleges provided a home for such a diverse range of disciplines that IDP work was considered a driving force within the college. In most cases, guest lectures, experimental courses, and permanent team-taught classes were not uncommon. In one instance, a particular course module was taught almost exclusively by faculty from another college. There were many examples of permanent cross-disciplinary programs within colleges and between.

While some of the deans asserted that IDP was a genuine trend, many expressed the view that future success depends upon a series of related factors; primarily the willingness of departments and department chairs to endorse this approach to teaching/research. Chairs require assurance in many cases that academic integrity and technical competence will not be compromised for 'transformative experiences.' IDP should be no less rigorous than their strict disciplinary counterparts. Yet, an additional problem was time. The problem with implementing an education with more IDP courses requires more units. There is a danger that in order to satisfy the demand for innovation across the disciplines some depth might have to be sacrificed within a department to allow breadth between them.

IDP courses fail to deliver if their purpose is not clearly defined in advance. This is crucial for faculty, administrators, and students because of the relatively higher workload involved. With committed faculty and administrators, however, the benefits are sufficient enough to offset some costs. Yet, in instances where colleges are unable to market IDP as part of 'executive education' often the only means to cope with rising costs is by increasing enrollment.

In addition, the greater the number of tenure-line/tenured faculty that are drawn to IDP courses, and away from their departments, creates additional burdens on departmental budgets as temporary faculty are hired to take their place. Students who choose to remain within the disciplines, in turn, resent the reduced amount of contact with full-time professors.

A practical side-effect of departmental 'entrenchment' is competition for limited resources. Department chairs must justify the allocation of resources, especially in publicly funded institutions that experience period funding crises, and this requires faculty to teach within the discipline thereby reducing the possibility of experimentation with IDP teaching and research.

The disciplinary acculturation that occurs in graduate school is perpetuated by the structural realities (disciplinary divisions) of academic life. Students are trained as they enter professional associations and then become missionaries for their own disciplines. This hinders the development of IDP because people tend to remain academically focused within the disciplines, often continuing research programs they began at graduate school and that were endorsed by leading academics. It is a reality that in order to secure tenure within a department a faculty member must become recognized as an original contributor to a discipline (through peer reviewed journals and book publications).

In summary, interdisciplinary courses are time-intensive, and are difficult to implement and maintain without properly coordinated efforts from faculty and administration. Both groups tend to differ on the amount of release time 'necessary' to develop and maintain interdisciplinary courses. Administrators unfamiliar with the demands of teaching in an interdisciplinary environment are unlikely to recognize the unique challenges, including the development of coordinated lecture topics and assessment across different subject areas.

4.5 Benefits

Significant educational benefits were found in this pilot effort, as well as unexpected benefits to faculty scholarship and to the university.

Educational benefits: The undeniable educational benefits are significant and compelling reasons to overcome the challenges associated with interdisci-

Please indicate your level of agreement with the following statements as a result of taking this course:

	1 completely disagree	2 somewhat disagree	3 neutral	4 somewhat agree	5 completely agree	Avg	Std Dev
I understand the role of my discipline in society better.	4.80% 1	4.80% 1	14.30% 3	38.10% 8	38.10% 8	**4**	**1.0954**
I understand the role of other disciplines in society better.	4.80% 1	0.00% 0	4.80% 1	52.40% 11	38.10% 8	**4.1905**	**0.9284**
I am more enthusiastic about my discipline.	4.80% 1	0.00% 0	33.30% 7	28.60% 6	33.30% 7	**3.8571**	**1.0623**
I am more interested in learning about other disciplines.	9.50% 2	4.80% 1	9.50% 2	33.30% 7	42.90% 9	**3.9524**	**1.2836**
My communication skills have increased.	4.80% 1	9.50% 2	14.30% 3	42.90% 9	28.60% 6	**3.8095**	**1.1233**
My teamwork skills have increased.	4.80% 1	9.50% 2	4.80% 1	38.10% 8	42.90% 9	**4.0476**	**1.1609**
I am interested in working in fields related to sustainability upon graduation as a result of this experience.	4.80% 1	0.00% 0	9.50% 2	33.30% 7	52.40% 11	**4.2857**	**1.0071**

Fig. 3. Student indication of level of agreement with statements probing attitudes and soft skills as a result of taking this course.

plinary teaching. In Fig. 3, the students were asked to indicate their level of agreement with statements provided as a result of taking this class. The statements probed students' attitudes towards the involved disciplines and the sustainability field in general.

An impressive 76% of the students agreed or completely agreed that they understand the role of their discipline in society better, and 91% agreed or completely agreed that they understand the role of other disciplines in society better as a result of taking this course. One student wrote, 'It made me understand what skills or assets I can contribute to the group.' An engineering student wrote, 'The project proved an excellent area to study that I would not have considered nearly as significant before, and I discovered many areas throughout the course which I may be able to contribute to engineering solutions.' In addition, over 60% of students are more enthusiastic about their discipline, and 76% are interested in learning more about other disciplines. As another student wrote, 'I did get a better understanding of other disciplines and am very happy that I am an engineer.'

In addition, 80% of the students agreed or strongly agreed that their communication and teamwork skills have increased as a result of taking this course. It is well-corroborated by the prior literature that these soft skills are very effectively taught in an interdisciplinary format, and our result support this [4, 5].

Fully 85% of the students agree that they are interested in working in fields related to sustainability as a result of this course. In the authors' opinions, this is an incredible outcome for a general education course. One of us regularly teaches general education courses related to sustainability, and the same result is not achieved when the subject is taught by a single instructor. We hypothesize that significant credibility is added by interdisciplinary faculty teams, perhaps due to the faculty teams' ability to address a wider range of issues and the social proof of seeing students and faculty from a range of backgrounds converging on a common theme. Some of the quotes from the students supporting this include the following: 'I have changed from a skeptic to a believer; I even fancy that being a 'sustainability manager' might be a good second career for me.' Another student wrote, 'Green energy is critical to the overall health of the world. My future may very well be in this field.' Another wrote, 'I plan to pursue a higher degree with the focus of my research on an environmental topic, such as energy storage.'

The deans also recognize the educational benefits of interdisciplinary courses. Students benefit from developing a greater awareness of the strengths and limitations of their discipline. They also develop communication skills and awareness of others' points of views. There are relatively few opportunities for students to learn and then model these skills within a college setting. At its best, IDP teaching exemplifies the model of the university as a marketplace of ideas.

Benefits to faculty scholarship: Almost every faculty member reported some positive benefit from this class to their own scholarship. These ranged from an increased interest in using topics of sustainability in their teaching to collaborations with other faculty in the pilot on projects, papers, and grants. In fact, at least two papers (one being this paper) and three proposals have resulted because of the relationships fostered either with climate solutions faculty or motivated by this collaborative experience. For a few faculty, this was one of the most enjoyable and unexpected personal outcomes of the course.

The deans also recognize the scholarship potential of interdisciplinary projects. The experience for faculty and students can be transformative. Faculty benefit from high-level discussion among peers (something that the 'silo' culture at universities often prohibits) and, increasingly, are encouraged to develop IDP research agendas via funding agencies like the National Institute of Health (NIH) and the National Science Foundation (NSF). An additional benefit is alumni donations. Alumni who have participated in an IDP course often approach colleges directly wishing to fund such programs.

Three of the five deans interviewed reported a generally favorable response on the part of senior and junior faculty to IDP teaching and research. One respondent noted that while there may be resistance from faculty within departments this is generally not because of ideological commitments against IDP teaching/research. Rather, the major issue is resource allocation. However, on balance, there is an impetus towards IDP teaching as chairs wish to enable their faculty to pursue projects that interest them. While there are occasional concerns about disciplinary integrity, the enthusiasm of funding bodies like NIH and NSF to actively encourage IDP research has allayed some senior faculty concerns.

Benefits to university: A well-organized, clearly focused interdisciplinary teaching experience is a benefit to students, who develop marketable skills, and to faculty who can stimulate their own teaching by observing others and developing their own research profile. The correlation between the impact of a 'transformative student experience' due to interdisciplinary teaching and alumni donations has yet to be documented in detail [25]. However, many universities undoubtedly find it useful to market themselves as 'innovators in education' through successful interdisciplinary ventures. High profile cases of giving by donors who identify interdisciplinary teaching and research as the best approach to addressing complex, real-world problems that transcend traditional disciplinary boundaries, will undoubtedly increase the attractiveness of such ventures to senior administrators. This is a trend that seems set to continue along with increased scrutiny over the use of public funds for higher education.

IDP clearly has some very strong arguments in its favor. On a research level, some of the most innovative work tends to originate from people who are comfortable in more than one discipline. In the classroom, this can translate into encouraging students to develop the communication and listening skills they will need as future professionals required to analyze and understand complex problems and relay that information to individuals outside their discipline. The demand for these 'soft skills,' the ability to see and understand another's point of view is, arguably, a by-product of life in the global marketplace as people encounter others unlike themselves and are expected to develop 'flexible' approaches to personal career management, changing careers up to 7–8 times in their lifetime [26].

4.6 Future recommendations

The Climate Solutions course was approved as a permanent course based on the pilot effort, and plays a role in the College of Engineering's recent initiatives in sustainability, in addition to campus-wide general education.

The authors' recommendations for the future course, based on the assessment of the pilot, are the following:

- Maintain broad range of topics. The broad range of topics was rated as 'relevant and essential' on average by the students and faculty team, and was viewed as an essential feature of this course. The authors and other faculty team members felt that the educational benefits achieved with this format would not have been possible with a smaller subset of topics and/or instructors.
- Recruit and screen appropriate faculty team instructors. The faculty team is paramount to the success of this course, and one poor instructor has the capability of negatively impacting the students' perception of the rest of the course. Faculty should be systematically recruited based on their related scholarly activities, ability to manage student projects, and interest in interdisciplinary education. Although student team dynamics were also shown to be very important, this cannot be controlled to a large extent. The ability of the instructor to manage conflict and direct the project seems to mitigate negative student experiences to some extent.
- Organize extensively prior to implementation. The faculty team and administrators must decide on and agree to the important details of the course prior to its implementation. Comparing an IDP team-teaching course with one taught by a single instructor, it is much more important to work out in advance the lecture content and integration; grading criteria for all assignments and projects; and objectives of the course. The activities to increase faculty and student engagement should be carefully considered and designed, such as the project competition. Other suggestions from students and faculty include a larger project involving more faculty and students instead of small competing projects, and a critical debate among faculty showcasing different perspectives from different disciplines.
- Secure adequate financial and administrative support. Interdisciplinary team-teaching is resource-intensive, and sustainable financial and administrative support is critical for the long-term viability of this course. This fact is well-corroborated by prior literature [5,7]. Funds in the form of endowments, donations, and/or curriculum development grants should be actively pursued by the faculty and administration. If successful, this will allow for reasonable faculty loading and manageable student enrollment without undue financial burdens on the

participating departments. Without such a funding mechanism, the educational benefits found in the pilot will be negated by unmanageable enrollment, and recruiting talented faculty will be an impossible challenge. Independent funds would also ensure the continuity of the course irrespective of changes in administration, which will inevitably happen.

5. CONCLUSIONS

The most compelling reason to implement an interdisciplinary team-taught course in an area related to sustainability was found to be the educational benefits. The fact that 52% of the students rated the course as 'One of the best classes I've ever taken' and their enthusiasm for later work in the field suggests that the course was successful in inspiring many of them. Some of the participating faculty felt that the students' exposure to environmental activism and the empowerment this can promote was a big part of this success. One of the challenges in teaching climate change and sustainability is that some people feel overwhelmed by the scope of the issue and ultimately powerless to do anything about it. Through students' opportunity to work on solutions to climate change and by also seeing their colleagues' projects, most students appeared optimistic about what could be done and eager to continue this work. In addition, resulting faculty development in the form of scholarly activity was found to be a significant benefit of this collaboration. Challenges impacting the success of this course and interdisciplinary team-teaching in general included: organization and coordination of faculty and the broad range of topics; as well as the administrative realities of resource allocation and rewards. These challenges must be overcome for the long-term viability of this course.

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Jinny Rhee is an Associate Professor in the Department of Mechanical and Aerospace Engineering at San José State University, where she has been since 2002. Her interests include renewable energy technologies, thermal management of electronics, and multi-disciplinary/interdisciplinary education for engineers. Dr. Rhee completed a B.S. (1989), M.S. (1990), and Ph.D. (1995) at Stanford University, all in mechanical engineering. Dr. Rhee is an active member of ASME, IEEE—CPMT (Components, Packaging, and Manufacturing Technologies), and SWE (Society of Women Engineers).

Eugene Cordero is an Associate Professor in the Department of Meteorology at San José State University. His research interests are focused on understanding the processes responsible for long-term changes in climate through the use of observations and atmospheric models. Dr. Cordero is a coauthor on the WMO/UNEP 2006 *Ozone Assessment Report* and is currently participating in projects related to evaluating the models used for the IPCC *Fourth Assessment Report*. He also recently coauthored *Cool Cuisine: Taking the Bite Out of Global Warming*, a hybrid popular science book and cookbook that looks at the multiple connections between the food we eat and global warming.

Lawrence Quill is an Assistant Professor in the Department of Political Science at San José State University, where he has been since 2005. His interests include modern and contemporary political theory, applied ethics, and the political psychology of decision-making. Dr. Quill completed a B.A. (1994), M.A. (1996), and Ph.D. (2000) at the University of Essex, U.K. all in Government. He has published two books, *Liberty After Liberalism* (2005), and *Civil Disobedience* (2009), both with Palgrave, Macmillan. His most recently published journal article focuses on the politics of Higher Education policy in the United States.