A Broader Impacts Course for Engineering Graduate Students

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Abstract

This paper describes the development and first offering feedback of a course for engineering graduate students aimed at introducing students to the notion of broader impacts of engineering research. During the course, students explored ways in which an engineer's activities can potentially benefit society and contribute to the achievement of specific, desired societal outcomes. The course incorporated lectures from the instructor and invited speakers. Students developed a personal broader impacts plan that is aligned with their personal and professional interests and goals. Students demonstrated attainment of course outcomes through assignments, class discussions and a final project that incorporated one or more suitable broader impact efforts in the context of their technical research area. The first offering of the course was taken by 13 students and student feedback indicated that 90% of the students gained a better understanding of broader impacts, could better articulate the impacts of their research and understood the importance of intentional efforts to achieve specific societal outcomes.

Introduction

Engineers must communicate the potential impact of their work beyond just the technical aspects. The ability to develop and articulate how one's research benefits society and contributes to the achievement of societal outcomes are key skills for scientists and engineers in industry and academia. As a university, we must develop engineering graduates who recognize the importance of societal impact, are cognizant of ways to potentially achieve societal impact in the context of their technical expertise, and can effectively articulate their efforts in this arena [1]. There exist few courses that address these needs for graduate students and these have been aimed at the scientific disciplines such as biology and ecology or have focused on a particular activity such as community engagement or informal science education [2,3]. Upon hearing about such a course at the University of Florida developed by Prof. Bruce McFadden at a National Broader Impacts Summit, the author was motivated to develop a course for engineering students. At the time the course was developed and to the author's best knowledge, no such course existed that engaged the engineering disciplines and that provided a holistic view of broader impacts. The course was developed and initially offered in Spring 2016 in the College of Engineering at Iowa State University (ISU). For the purposes of this course, activities with specific societal impact were grouped into the areas of K-12 engagement, broadening participation, public engagement and promoting teaching, training and learning.

Course Content and Design

Titled 'Broader Impacts of Engineering on Society,' this 2-credit course was aimed at engineering graduate students, with no stated pre-requisites other than graduate standing.

The course objectives are to:

- Introduce graduate students to the notion of broader impacts of engineering research
- Inculcate a thinking in graduate students of the importance of broad based impacts of their work, both through communication strategies and planned efforts

Accordingly, the learning outcomes of the course were set forth as the following abilities that students should be able to demonstrate upon completing the course:

1) Understand the importance of the notion of broader impacts of engineering research
2) Provide examples of broader impacts activities that engineers engage in to potentially benefit society
3) Identify potential partners on campus to engage in broader impacts activities
4) Articulate the significance and potential impact of their research activities on society at large
5) Design and/or develop one or more broader impact activities in the context of their research

The course met once a week for approximately two hours of lecture and utilized a combination of lectures from the instructor as well as guest lectures from faculty and staff across campus with expertise in a particular topic related to broader impacts activities and selected TED talks and talks available on public sites such as YouTube. While the course did not have an assigned textbook, reading materials including journal papers and news articles were assigned. Table 1 shows the topics that were covered during the semester long course. At the time of the course development and initial offering, the author and course instructor served as Co-PI and platform leader for Broader Impacts on the Iowa NSF-EPSCoR grant and had significant experience in coordinating BI efforts. Guest lecturers with various subject matter expertise from across campus included Prof. Michael Dahlstrom from the School of Journalism and Communication (communicating with the public), Prof. Joanne Olson from the School of Education, Dr. Adah Leshem from the Center for Biorenewable Chemicals (K-12 engagement and pre-service teacher education) and Prof. Raj Raman from the Department of Agricultural and Biosystems Engineering (mentoring). In addition, as part of their learning about broadening participation, students were expected to attend at least 2 sessions of the Iowa State Conference on Race and Ethnicity, which is held on campus every spring.

Table 1: Schedule of topics covered during the semester long course.

Week	Topic(s)
1-2	Introduction to Broader Impacts
3	Explaining the impact of your work
4-5	K-12 engagement
6-7	Broadening Participation
8	Engaging the public
10	Promoting teaching, training and learning
11	Assessment of activities
12-15	Course Project: Objectives and Scope; Project details; Assessment plan and results if piloted

Assessment and evaluation of student learning

The major evaluative components of the course included in-class activities and discussion, homework assignments and deliverables associated with a final course project. Grades were assigned based on mastery of expected outcomes [4]. Students were given multiple opportunities to demonstrate attainment of the course outcomes through the following mechanisms:

- Assignments — Outcomes 1,2,4
- Class Activities (discussions and presentations) — Outcomes 1,2,3,4
- Course project — Outcomes 3,4,5

Each evaluative component was graded against a rubric that had scores for levels of demonstrated proficiency. Based on the mastery of the outcomes demonstrated by students via the evaluative components, grades were assigned ranging from A (attainment of all outcomes at a proficient level) to B- (attainment of 1 outcome at a proficient level).

Student Projects

Throughout the course, students were asked to maintain and continuously update a course journal. This journal consisted of entries similar to a diary in which students would reflect upon the broader impacts topic being discussed and record their level of personal interest and alignment of personal values with the goals and impact of that specific broader impacts (BI) activity. The intent here was for the students to identify an area of BI activity that aligned with their interests and motivations right from the beginning, rather than making a decision based on other factors. This approach underscores the philosophy that for individuals to develop a broader impact identify, alignment of personal motivations and interests is a critical factor towards sustained activities in that BI area.

Around week 12, students were asked to submit a written proposal that outlined in a synopsis format, the specific BI area for their project, the intended audience(s) to engage, a list of outcomes they expected from the project, a description of the activity, and a description of measures they would need to know if their project was successful in achieving the intended outcomes. Students met with the instructor to obtain initial feedback and guidance, and then were asked to share their project proposal via oral presentation to their classmates, who provided additional feedback. Students were encouraged to consult with subject matter experts (e.g. guest lecturers and other entities identified throughout the semester). Key topics that most students needed guidance on were on the following project attributes, which are often seen when faculty seek to develop BI activities as well.

1) Ensuring specificity of the BI activity as opposed to a broad audience which would render the activity too broad and
2) Ensuring students were thinking about measures of success as a best practice and necessary component for improving their activity.

Subsequently, students worked on their project topics and gave a final oral presentation during the final week of the semester. The format of the final presentations included: 1) Project objectives and intended outcomes; 2) Motivation and rationale; 3) Project description and; 4)

Assessment plan. Students were encouraged to explore the possibility of piloting or 'practicing' their BI activity. Table 2 lists the 13 student project titles and the BI area that each project addresses.

Table 2: Listing of student projects. An asterisk indicates a project which was piloted or implemented following the conclusion of the course.

Student	Title	BI Area
1	BEAM: Broadening participation via K-12 engagement*	K-12/Broadening Participation
2	Fun with friction*	K-6 engagement
3	Educating and engaging the Ames community with ISU: Knowledge on tap*	Public engagement
4	Introduction of Industrial Engineering principles to high school students*	K-12 engagement
5	Exploring engineering through hopping droplets*	K-12 engagement
6	The broad impact of Computational Fluid Dynamics (CFD) for ISU undergraduate students	Teaching/Training/ Learning
7	Broad dissemination of superhydrophobicity: There's an App for that!	Public engagement
8	Participation in the future engineering program	K-12/Broadening Participation
9	Why is the sky blue? Why is the sunset red?	K-12 engagement
10	Broader impacts of biorenewables: Educating K-12	K-12 engagement
11	Introducing interesting science activities to elementary school kids at the Des Moines Science Center	K-6 engagement
12	Connecting the dots: A new mentor hub	Broadening Participation
13	Mentoring undergraduates to improve presentation skills	Teaching/Training/ Learning

The BI areas addressed by the students were predominantly K-12 engagement, followed by broadening participation, public engagement and teaching/training and learning. It is worth noting that in the K-12 arena, students selected specific age groups for their intended audience (e.g. elementary or high school students). This suggests that students understood the importance of specificity in the selection of the audience, a fact that was emphasized by Prof. Michael Dahlstrom, the guest speaker from the School of Journalism who spoke on communicating with the public. Some projects of note are listed below to highlight the range and impact of the projects.

1) <u>Connecting the Dots: A New Mentor Hub (project 12)</u>: This project was developed by an off campus (distance education) student, who being a professional in the IT industry, focused on a mentor selection portal that focused on listing attributes rather than photographs of mentors. The rationale here was that by matching described attributes between the mentee

and the mentor in the absence of photographs, the effect of implicit bias in mentor/mentee selection can be reduced and participation of under-represented groups can be increased.

2) Fun with Friction (Project 2): Another project focused on helping elementary students understand the concept of friction. This was developed by a graduate student whose research expertise was in the area of tribology (friction, wear and lubrication). The student developed a 'ramped race-car' activity that allowed students to understand the notion that surface finish and texture can impact resistance to motion (Fig. 1). The graduate student was able to 'pilot' his activity in a 3rd grade class at a local elementary school in Ames, IA and obtained a good experience and feedback. His comments after the activity included *'...I never thought how challenging it would be to explain such a simple concept to the children while trying to get them excited about the subject!'*.

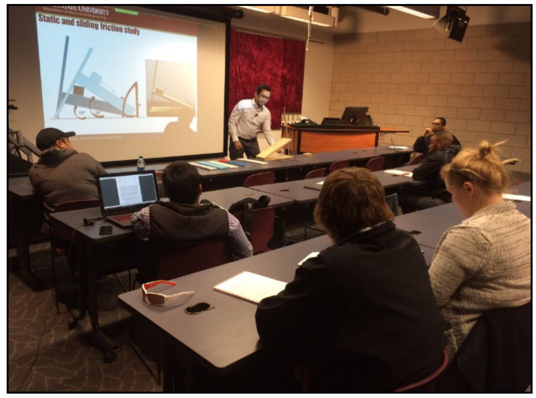

Fig. 1: A mechanical engineering graduate student demonstrates his ideas for hands-on friction experiments designed for 3rd -4th graders. He deployed this to 3rd grade students at a local Elementary School in May 2016.

3) Knowledge on Tap (Project 3): Another graduate student focused on developing a forum for engineering faculty to communicate the impact of their research to the Ames, IA community and wanted to develop a series similar to Science Café. Working with a local microbrewery, she was able to launch this program, titled 'Knowledge on Tap' during the summer following the course (Fig. 2). The program featured three talks during the summer and is now a formal program in Ames, IA with coordination and leadership being provided by engineering graduate students in the Human Computer Interaction program.

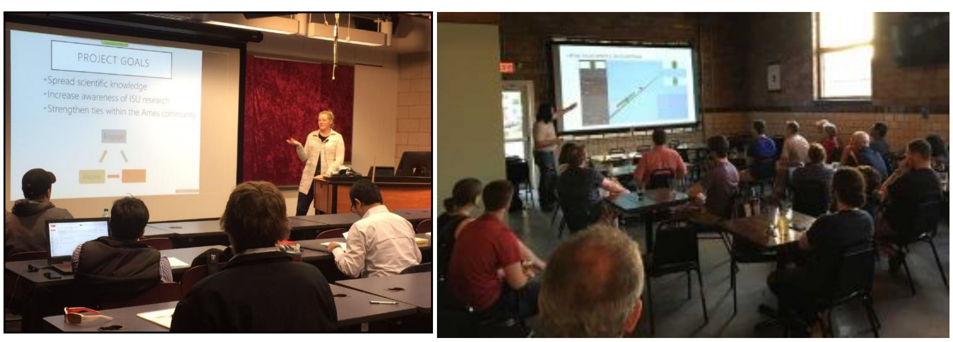

Fig. 2: (Left) Another mechanical engineering graduate student describes her plan for science café-like events at a local brewery. The first event for this 'Knowledge on Tap' was held in June at the Torrent Brewing Company (Ames, IA) on microfluidics research (right). Awareness for the events were through social media.

Assessment, evaluation and feedback

Thirteen (13) students from four engineering disciplines enrolled for the first offering of the course, one of whom was an off campus (distance engineering) student. Since the course employed grading based on mastery of outcomes [4], the course grade is a direct assessment measure of the achievement of outcomes by the students. 11 of the students achieved an A, indicating they demonstrated proficiency in achieving all outcomes. 1 student obtained an A- while one student obtained a B+. These students typically did not meet proficient levels for outcomes 4 and 5 (communicating the impact of their research and designing and developing a BI project). Thus 85% of the students were able to demonstrate achievement of all learning outcomes. Students were also asked to self-assess their achievement of the stated learning outcomes through a Likert-type survey. The survey results are shown in Table 3 below.

Table 3: Results from self-assessment survey (post-course)

Self-assessment question	Response
1. How would you describe your awareness and understanding of broader impacts of engineering' prior to taking this class?	Minimal (23%) Moderate (38%) High (38%)
2. After taking the course, I better understand the notion of broader impacts of engineering research	Strongly agree (92%)
3. After taking the course, I can provide examples of the kinds of broader impacts activities engineers can engage in to potentially benefit society	Strongly agree (77%)
4. After taking the course, I believe it is important for engineers to engage in activities that contribute towards specific desired societal outcomes	Strongly agree (85%)
5. After taking the course, I can better articulate the significance and potential impact of my research/professional work and broader impact activities	Strongly agree (62%) Agree (31%)
6. The topics addressed by this course were helpful for my education and personal growth as an engineering graduate student	85% Strongly agree

The results indicate that the majority of the students who took the course felt they were able to demonstrate achievement of the learning outcomes (questions 2-5). The students also felt that the course was helpful for their personal growth as an engineering graduate student (question 6). It appears that students were less confident about their ability to communicate the impact of their research (question 5). Student comments from the end-of-semester course evaluations included the following statements regarding the structure and format of the course:

'I really enjoyed having a variety of speakers come in. In addition, talking about a definition of broader impacts the first few weeks of class helped me set up a good foundation for the rest of the course.'

'I thought the class participation very beneficial and should be required. We were able to not only practice talking about our research to others but we were able to see how we progressed throughout the semester.'

Summary and outlook

The initial offering of the course in Spring 2016 attracted 13 engineering graduate students from four disciplines and introduced them to the notion of broader impacts and underscored the value of engaging in activities to achieve specific societal outcomes. Student feedback from this initial offering was very positive. The course has already achieved impact by enabling students to implement their project ideas and build confidence and understanding of designing, developing and deploying broader impacts efforts. The current offering of the course has been modified based on feedback to provide more time for project development and an increased emphasis on communicating the impact of the students' research. The course is expected to be offered on a regular basis and can help contribute to a more broadly educated and socially engaged engineering workforce.

Acknowledgments

Course development was supported in part by the National Science Foundation Grant Number EPSC-1101284. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. Special thanks to the guest lecturers who committed their time to sharing their expertise with the students and to Prof. Bruce McFadden for his advice and input on developing the course.

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