The Sky's the Limit: Drones for Social Good

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Work In Progress: The Sky's the Limit: Drones for Social Good

Abstract

A full semester course, with a focus on engineering design to promote social good, was developed for second-year engineering students. The course, *The Sky's the Limit: Drones for Social Good*, engages students with drone technology as well as the awareness of the needs, challenges, and resources of diverse communities and how drones can serve these communities. Humanities, ethics, and human centered design are explored in the context of engineering, and interwoven throughout the semester. *The Sky's the Limit: Drones for Social Good* course includes critical aspects that relate to multiple engineering disciplines, which allows students to identify the connections between drones and their particular engineering concentration. The course is also multi-disciplinary and encourages critical social reflection. Students consider a broad range of applications of drones with the goal of promoting social good. The course culminates in an entrepreneurial project that incorporates knowledge and skills from several engineering disciplines in the context of engineering for social good.

Research has found that female, Black, and/or Latinx engineering students are drawn to pursuing careers that they identify as promoting social justice and a greater social good. Our course should aid in retention of female, Black and Latinx students, by engaging students in a semester-long, project-based engineering course in which they develop applications of drones that are designed to benefit diverse communities.

As part of Rowan University's engineering program, all second-year students majoring in engineering take a project-specific sophomore engineering class (SEC) during their spring semester. Our course, *The Sky's the Limit: Drones for Social Good,* was taught to a small subsection of students taking SEC. SEC courses are generally taught in sections of 20-24 students. Students self-select for the project of their preference and about 80 students self-selected to work on the drones for social good project. In future work, assessment of the success of the course curriculum will be completed through qualitative analysis of student reflections, interviews and document analysis of student work. Additionally changes in students' attitudes towards engineering and social responsibility will be assessed through quantitative analysis.

Introduction

Social Responsibility, Social Justice, and Ethics in Engineering Education

Developing engineers who are capable of understanding their social responsibility in the world is becoming increasingly important. This has been recognized by the Accreditation Board for Engineering and Technology, Inc. (ABET) which, as part of their 2019 - 2020 criteria for accrediting engineering programs, includes the following student outcome for ethical decision making: *"... consider the impact of engineering solutions in global, economic, environmental, and societal contexts"* [1]

In some engineering programs, ethics is studied as a unit within a course that is otherwise focused on engineering while, in other cases, separate courses in ethics have been offered. Some studies have found that engineering ethics, offered in this manner, have not resulted in students being able to apply ethics in actual engineering practice. With respect to ethics units offered as separate entities within engineering classes, Newberry argued that making them separate, rather than integrating ethics throughout the curriculum makes ethics seem unimportant and illegitimate [2]. Similarly, Leyden & Lucena found that when ethics and consideration of the social impacts of engineering are addressed through courses that are distinct from engineering courses ". . . *they will occupy a marginalized position in engineering education and sociotechnical thinking will not be seen as integral to "real" engineering*" [3]. Hess and Fore (2018) state that humanities, ethics, and engineering should be interwoven so they are considered simultaneously during the entire design process by using "micro-insertions" of ethics rather than large units or distinct courses [4].

Riley [5] provided one of the first "roadmaps" for engineers to study the intersection of social justice/peace and engineering. Many others are now working to develop curriculum to bridge these two seemingly different fields of study [3],[5],[6]. Many times social responsibility in engineering is incorporated into engineering degree programs via service-learning, volunteerism, clubs, etc.; however, sometimes the mark is missed because students do not fully understand the "*inequalities and injustices among those helping and those being helped*" [3].

Our course, *The Sky's the Limit: Drones for Social Good,* was designed to engage engineering students with concepts of social justice integrated into an engineering curriculum. While some engineering classes introduce themes of social awareness, such as ethics, into the curriculum, the presentation is often done as a discrete class component lasting for a week or so. The inclusion of social justice material in this course was designed to span the entire duration of the class. Thus, our primary expected outcome is an increase in appreciation for the manner in which drone engineering can be directed toward social good, in particular, and a broader appreciation for the fact that engineering, in general, can also be directed to social good. We expect that continued iterations of this course will increase the students' understanding of how to align engineering work with social good and will also lead to increased enrollment and retention in engineering programs.

Benefits to Historically Underrepresented Students

A key long-term goal of our course is an increase in the recruitment and retention of female, Black, and Latinx students in our university's engineering program. Research by Capobianco and Yu at Purdue University discovered that young girls often do not participate in engineering disciplines because they do not see it as a "caring" profession [7]. Rulifson and Bielefeldt also indicated in their research of women engineering students, that women left engineering programs for the same reason [8]. The findings indicate that female engineering students show a high degree of interest in projects that are seen as having a positive benefit on society. McGee and Bentley [9] found patterns, similar to the gender preference, among Black and Latinx students. Within the category of "science and engineering" the NSF identifies mathematics, hard sciences, engineering, as well as social, behavioral, and economic sciences. According to Camacho and Lord, Latinx students who study in the NSF category of “science and engineering” typically choose psychology and social science, both disciplines within behavioral sciences, ahead of engineering [10]. Therefore we propose that increasing the social relevance of engineering could increase the population of women students as well as Black and Latinx students.

Our course, *The Sky’s the Limit: Drones for Social Good,* is designed to promote student interest in engineering by presenting an engineering challenge, namely, drone technology and its application, in a context through which students can see the positive social benefits. In addition to the conspicuous forms of diversity, such as racial/ethnic and gender diversity, there are other less conspicuous/invisible forms of diversity such a socio-economic standing, education level of family members, values and beliefs. There may be members of these groups, in addition to students from both the gender and racial minority and majority populations, that will be inspired by the opportunity to pursue engineering goals that have positive social impact and have the potential to be used in the US and in other locations around the world.

Students who graduate from most engineering programs enter a profession in which they are likely working for a broad range of clientele that may extend beyond national borders. Thus, our engineering programs must provide students with coursework and experiences that prepare them to excel in this globalized engineering world. Students need the knowledge, skills and experience working with a diverse group of people and projects. By having students work on projects that can be used by people of diverse backgrounds they will also become more socially conscious individuals.

Course Specifics:

Why Focus on Drones?

Drones have been identified as the focus of instructional curriculum due to their rise in popularity and utilization and because of the wide range of engineering/science concepts involved in their design and potential applications. While historically, drones were developed for military applications, Choi-Fitzpatrick, Chavarria, Cychosz, Dingens, Duffey, et. al, [11] found that by 2012, the non-military uses of drones overtook military uses. With the widely reported use of remotely operated drones in military and police operations it is not surprising that many people associate public use of drones with these applications, however many are also aware of the commercial and potential commercial uses of drones - such as Amazon’s proposed product delivery system - and many are aware of the use of drones as a toy/hobby. There are also a significant number of humanitarian uses of drones, however, these uses tends to be less commonly associated with drones.

Model Course: Engineering Peace at UCSD

Our course, *The Sky's the Limit: Drones for Social Good,* is modeled on a similar "Peace Engineering" course developed by Gordon Hoople and Austin Choi-Fitzpatrick at University of California San Diego (UCSD)[12]. While Hoople and Choi-Fitzpatrick have helped provide a framework for our course, there are significant differences between the course taught at Rowan university and the course taught at UCSD. Primarily, Hoople and Choi-Fitzpatrick's course was a multi-disciplinary course in which about half (14) of the students were engineering students and about half (10) were peace studies students. Hoople and Choi-Fitzpatrick designed their course to focus on intercurricular collaborations between engineering students and peace studies students. At our university, Rowan University, engineering classes are composed, exclusively, of engineering students. Additionally, the school does not have a peace studies program; however our university offers a certificate that focuses on social justice and social change.

An additional distinction between our courses and the UCSD course is the fact that, though the student class time is the same, the course at Rowan University earns the students only one credit, while the course at UCSD earns the students three credits [12]. Thus, students in our course may have a lower relative motivation to dedicate time to the course in comparison to students taking the "Engineering Peace" course offered at UCSD.

Rowan University SEC Model Course

As part of the Spring 2019 course offerings, we are testing our course, as part of Rowan University's second semester sophomore level engineering class (SEC). SEC is taken by all sophomores majoring in Engineering during the spring semester. It is a combination of a public speaking course and an engineering lab; however, both classes are taught relatively independently. The engineering component of SEC is worth 25% of the student's overall grade for SEC, while the public speaking portion is 75%. Project offerings are presented to students on the first day of the class upon which, the students select based on preference. Students self-select to be in a particular offering of SEC, available during their scheduled class time. Different course projects this year included: biomaterials, entrepreneurship, Chem-E-Cars®, and rocketry. This semester, 77 students self-selected to be in our course. The 77 students were divided into three different classes. Each of these classes was team-taught by at least two engineering professors.

Our course, *The Sky's the Limit: Drones for Social Good,* was part of a broader effort supported by a highly competitive NSF grant focused on diversity, which was awarded to the engineering department at our university and supported by the Faculty Center for Excellence in Teaching and Learning. This grant supported development of inclusive curriculum and materials. Our course curriculum covered basic concepts on the design of radio controlled drones as well as applications of this technology for social good.

Weekly Class Structure

A unique feature of our course, was the incorporation of social justice concepts and technical engineering concepts into each class. A template of the course material is shown in Table 1. Each class included some interactive activity in which students engaged in discussion and reflection on topics related to social justice. There were also technical presentations of engineering concepts related to drones in each class; students then worked on designing their drones and identifying a socially beneficial use for their drone. For the first five weeks of the course, each class had two discussions, one technical in nature, the other focusing on the social implications of engineering. For the remaining eight classes, students continued technical presentations, worked on their social beneficial application of drone technology, and designed a quadcopter drone.

Table 1. Weekly schedule of engineering and social justice topics.

Week	Engineering Topic	Social Justice Topics
1	Introductory Presentation	What is social good / Social justice?
2	Propeller Theory	Engineering Mindsets
3	Chassis/Frame and Duct Theory FAA Regulations	What are engineers involved in?
4	Flight Controllers Motors	Problems with service
5	Guest Presentation - Jerry McCann - Peace Engineering	Solutions that Work
6	Batteries	Entrepreneurship and Student Project
7	Radio Transmitter/Receiver	
8	Build/Revise	Initial Project Pitch
9	Build/Revise	
10	Build/Revise	
11	Practice Pitch	Reflections on Student Proposals for Social Good Use of Drones
12	Competition	
13	Final Presentations	

Even though many students have access to information regarding current global events, we wanted to make sure students were initiating the discussion of social justice/good with a similar definition. The first class was dedicated to examining the student's perspective on social justice. The students were asked to answer the following questions: *1) What are the major concepts of* *social justice? 2) What are the connotations of social justice? 3)Where do social justices occur? 4) What technology (if any) can improve conditions of social justice?* A class forum followed in which students shared their answers and were tasked to find trends for each question. The students then completed a written reflection which had them answer the question: “What is social justice?”.

The second week focused on exploring the student’s perception of what engineers do. The second interactive discussion used a gallery walk of the jokes included in Chapter 2 of Riley’s “Engineering and Social Justice”. The students evaluated the accuracy of the stereotype depicted in the jokes as well as whether they found the joke humorous. They could also correct the joke if possible to make it more true. The class shared their overall opinions and were tasked with selecting one joke and writing a reflection on whether they agreed/disagreed with the stereotype and why. The technical discussion was focused on the forces acting on drones during flight. Students used a computational fluid dynamics simulation program, COMSOL Multiphysics®, to model forces on airfoils.

During the third week, we had students investigate major problems facing the world’s population and then determine which of these problems engineers could actually solve. We had our students identify links between the problems they found and the National Academy of Engineering (NAE) Grand Challenges of Engineering. To determine if students’ career paths generally led to solutions for these problems, they were given statistics that showed the companies that are the major employers for Rowan University graduates. This encouraged students to reflect on their future career paths and to consider whether the companies they may work for are providing solutions for either the problems students identified or the NAE Grand Challenges of Engineering. The technical discussion focused on developing the chassis for the drone. Several student groups also gave technical presentations on the topic of FAA regulations for small drones.

During weeks four and five, we had students explore many issues related to engineers collaborating with communities, particularly marginalized communities in the developed and developing world. Student teams read a specific section of Ivan Illich’s, “To Hell with Good Intentions” and answered relevant questions. Groups presented a summary of their section and discussed their answers with the class. Following these presentations, we had students consider lessons learned from examples of mistakes engineers have made while trying to solve problems facing marginalized communities. We also brought in a speaker, Jerry McCann, who discussed his experiences working on Peace Engineering projects in collaboration with communities in developed and developing areas of the world. Jerry’s presentation, during week five, focused on solutions that worked when implementing socially good engineering. The technical discussion, during these weeks, involved student presentations on motors and flight controllers. Students also continued to work on designing their drone chassis. An example of a drone developed during SEC is seen in Figure 1.

Figure 1. Quadcopter with front-facing camera.

After students examined social injustices, identified the typical employment opportunities for engineers, reflected on problems that arise when trying to promote socially good engineering, and considered strategies for successful community based collaborations, they were tasked to develop an application of drones aimed at promoting social good. For the remainder of the course (weeks 6 through 13), social justice concepts were threaded via an social entrepreneurial application of drone technology. Students' entrepreneurial pitches assessed the viability and socially good aspects of their drone technology. A list of some applications of drone technology that students developed is presented in Table 2.

Table 2. Selected student engineering-related applications of drones

Food	Collect data on land (trees/crops) in order to improve agricultural production.
Water/Air	Perform water testing (heavy metals, dissolved oxygen, turbidity, coliform, etc.); perform air testing on volatile organic compounds (VOCs)
Materials	Deliver materials (such as medicines and equipment) to remote areas.
Waste/Environmental Cleanup	Monitor oceans to assess the removal of plastic to establish locations that are in need of intervention.
Health Care	Deliver materials (such as medicines and equipment) to remote areas.
Diversity and Inclusion	Drones to enable people with physical or cognitive challenges to engage in sporting/recreational fishing.
Infrastructure	Flyovers after a natural disaster to determine areas in need of support.

Preliminary Results

At the beginning of the semester, before any instruction took place, students from all sections of SEC - those enrolled in our course project and those enrolled in purely engineering projects - were given a survey. The survey included questions on student background and student attitudes towards engineering and social responsibility[13],[14]. Our initial survey resulted in 236 completed surveys out of 272 students currently enrolled in SEC. The demographics of all students who completed the survey are presented in Tables 3.a through 3.c.

Table 3.a: Gender of our university's SEC Student population

Gender		
	Number of Students	%
Male	175	74.2
Female	59	25.0
Prefer not to answer	2	0.8

Table 3.b: Race/Ethnicity of our SEC Student population

Race/Ethnicity		
	Number of Students	%
White	198	81.1
Asian	23	9.4
URM*	19	7.8
Other	4	1.6

*URM includes Native American, Hispanic, Black, Native Hawaiian

Table 3.c: Engineering Disciplines of our SEC Student population

Engineering Disciplines		
	Number of Students	%
Mechanical Engineering	64	27.1
Civil Engineering	53	22.5
Electrical and Computer Engineering	43	18.2
Chemical Engineering	40	16.9
Biomedical Engineering	29	12.3
Entrepreneurial Engineering	7	3.0

Preliminary results from the survey questions on attitudes towards engineering and social responsibility are shown in Tables 4 and 5, below. Table 4 has results from the question: *Why are you studying engineering?* Table 5 has the results of the skills that are necessary to becoming a successful engineer. Of note is that students rank "e*ngineering skills can be used for the good of society*" and that "*engineers have contributed greatly to fixing problems in the world*" as among the highest reasons for studying engineering. At the same time, however, students rank cultural competency and social awareness as relatively low in importance to becoming a successful engineer. This represents a contradiction between their self-identified reasons for studying engineering and the skill set necessary to be a successful engineer. Cultural competency and social awareness are crucial for the success of engineering projects that solve problems around the world and promote social good. Future research will investigate the degree to which our students have changed these and other perceptions.

Table 4. The reasons why students choose to study engineering.
(Scale: 1 = Not a reason, 4 = Major reason)

	μ	σ
Technology plays an important role in solving society's problems	3.29	0.77
Engineers make more money than most other professionals	3.23	0.76
My parent(s) would disapprove if I chose a major other than engineering	1.5	0.81
Engineers have contributed greatly to fixing problems in the world	**3.51**	**0.73**
Engineers are well paid	3.3	0.74
My parent(s) want me to be an engineer	1.86	0.98
An engineering degree will guarantee me a job when I graduate	3.32	0.81
A faculty member, academic advisor, teaching assistant, or other university affiliated person has encouraged and/or inspired me to study engineering	1.89	1.04
A non-university affiliated mentor has encouraged and/or inspired me to study engineering	2.43	1.15
A mentor has introduced me to people and opportunities in engineering	2.11	1.09
I feel good when I am doing engineering	3.3	0.81
I like to build stuff	3.44	0.82
I think engineering is fun	3.5	0.7
Engineering skills can be used for the good of society	**3.58**	**0.71**
I think engineering is interesting	3.76	0.53
I like to figure out how things work	3.76	0.56

Table 5. The skills/abilities students believe make a successful engineer.
(Scale: 1 = Not important, 4 = Crucial)

	μ	σ
Self-confidence (social)	3	0.75
Leadership ability	3.17	0.69
Public speaking ability	3.2	0.71
Math ability	3.37	0.69
Science ability	3.37	0.62
Communications skills	3.54	0.58
Ability to apply math and science principles in solving real world problems	3.65	0.55
Business ability	2.57	0.73
Ability to perform in teams	3.61	0.56
Cultural competency	**2.85**	**0.9**
Social awareness	**2.97**	**0.81**
Ethics	3.56	0.65

Conclusion

The SEC students who took our module were given an opportunity to learn social justice by applying drone technology to solve a variety of engineering problems. They also had an opportunity to see how their technical skills could be transitioned into an entrepreneurial project. Many students within engineering lack the awareness of using engineering to promote social justice and this curricular development is an integral step in developing this key aspect of our students awareness of social responsibility. Additionally, a study on 300 engineering students [15] found that students' social awareness tends to decline between the time that they begin their educational careers and the time they earn their degrees. We designed *The Sky's the Limit: Drones for Social Good* course to help offset this tendency by offering an opportunity for reinforcement of social awareness. The course integrated learning drone technologies with reflection on social justice and the social impact of the technology. We structured the course to maintain this integration throughout the semester so that students would learn to be conscious of the connections between engineering and society, and to encourage students to appreciate the potential engineering has to promote social good. We have collected data from surveys and student reflections, and will evaluate it to assess to degree to which we have been able to encourage students to consider social justice and the social impact of engineering. Finally, since it has been shown that women, Black, and Latinx want to participate in "caring" occupations, we feel that our course has the potential to make a positive impact on the recruitment and retention of engineers from these groups. Future research should investigate the degree to which our course, *The Sky's the Limit: Drones for Social Good,* leads to an increase in recruitment and retention among women, Black, and Latinx students.

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