Toward the UN's Sustainable Development Goals (SDGs): Conservation Technology for Design Teaching & Learning

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Abstract
Interdisciplinary capstone team projects provide a diverse array of student experiences and have been shown to improve a team's innovation, analysis, and communication. The UN's 17 Sustainable Development Goals (SDGs) provide aspirational, human-centered design opportunities for applying engineering practices to real-world interdisciplinary technology interventions that aid in programs from public health to wildlife conservation. In this sophomore-level design course, we focus on climate change, impact of life on the sea, and the impact of life on the land SDGs through the lens of conservation technology. Conservation Technology (CT) is a relatively new field that focuses on the creation of technologies to promote and safeguard sustainable human-wildlife interactions. In this manuscript, we describe the framework for teaching a Conservation Technology project-based capstone engineering course and present observations of mono-disciplinary and interdisciplinary team practices. When working in a mono-interdisciplinary team, engineers tended to focus only on the design deliverables and missed challenges imposed by policy, biology, and computational requirements. These types of challenges are nearly always present in conservation technology interventions and cannot be overlooked. In contrast, the interdisciplinary team was able to better identify the diverse challenges associated with conservation technology interventions. This work-in-progress paper focuses on the development of an organized curriculum to teach conservation technology to first- and second-year engineers to allow them to work towards more sustainable engineering practices. Universities are working to inject the SDGs into engineering curricula, and we believe Conservation Technology is an ideal fit for combining the engineering design process with the scientific method to discover new types of possible failures in design and create innovative solutions for a sustainable future.

Keywords

Human-wildlife-centered design - Project based learning, Engineering design – Mechanical Engineering Design – Vertically-Integrated Project

Introduction

In 2015, the United Nations proposed 17 Sustainable Development Goals (SDGs) designed to create a more sustainable future for our world[1]. Much like National Science Foundation's 10 Big Ideas or the Grand Challenges, the SDGs also serve as a framework for academic research, scholarship, and service[1-3]. The UN has worked over the past few years to increase the amount of pedagogical information attached to the SDGs to help leverage them into courses through academia, including guides to teaching, sample learning outcomes, and course assessments[4]. The SDGs all have bases in engineering ethics and education ranging from topics on global warming, sustainable cities, and world hunger[5]. While there are many ongoing research projects throughout the United States dedicated to more sustainable energy solutions and reduction of warming at the global scale, few universities are focusing on conservation of wildlife. The SDGs goals of 'life below water' and 'life on land' aim to mitigate the effects of human-wildlife conflict imposed by habitat loss and species extinction. An increasing number of startup companies including Open Acoustics, Conservation X Labs, Internet of Elephants, WILDLABS, and Conservify are working to counteract the global extinction crisis and have built a new field known as Conservation Technology[6].

Conservation Technology (CT) is an overarching term for developments in the wildlife and environmental conservation fields. Much of the existing CT implements modern hardware and software design processes to improve upon ongoing conservation efforts and initiate previously under-addressed efforts[7]. Some of the major goals of CT are to improve outdated equipment, increase accessibility to tools, and use modern technology to address conservation problems in entirely new ways. For wildlife in particular, CT is being developed for both in animals' natural environments (in-situ) and in captive settings (ex-situ) approaches (i.e., foxes and elephants, respectively)[8]. Initially, the wildlife community was dismissive of new technologies, but it has recently begun to accept and even assist in the development of new conservation tools and solutions. Unlike other engineering endeavors, every technological development must be properly defended by establishing the necessary bridges between the conservation community, technologists, and policy makers [7,9]. A new technology is not considered CT until its genuine usefulness and success is ensured.

Activities and Methodology

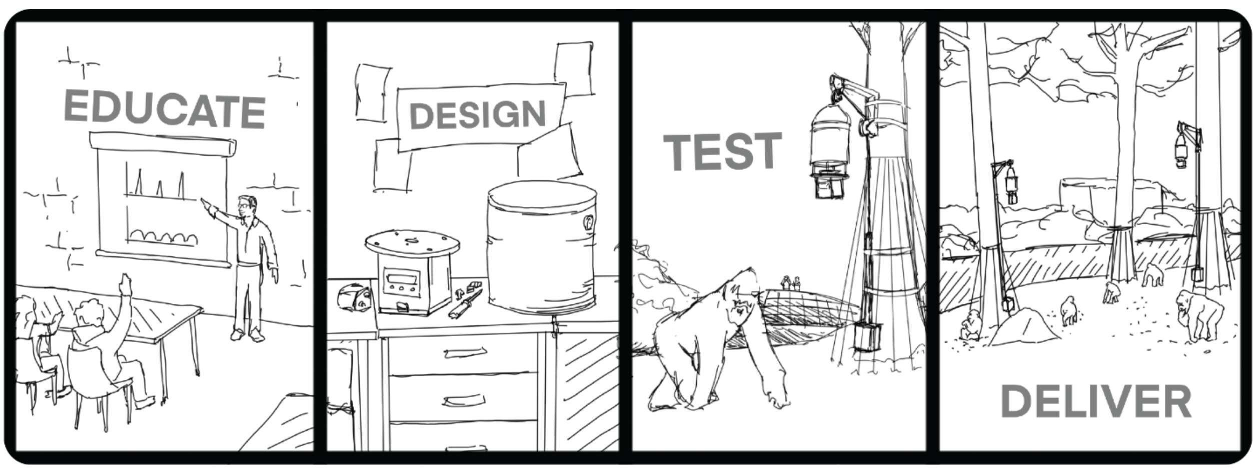

Figure 1. Four phases in educating undergraduate students on conservation technology using project-based learning. Illustration done by B. Seleb.

At Georgia Tech, we currently teach an undergraduate, interdisciplinary project-based course on CT called Tech4Wildlife. This course is taught to sophomore through senior level students via the university's interdisciplinary project-based course program, Vertically Integrated Projects (VIP). The course is built upon a four-phase learning framework (**Figure 1**). The course structure begins with **education** on broad concepts including human-centered design, conservation science, frugal technology, and technological interventions. We then pair interdisciplinary student groups with conservation leaders in the field who provide specific expertise on the impact species and existing technology. This specific expertise from conservation leaders helps students **design** a conservation tool better suited to help the conservation organization and the impacted species. Students work through the engineering design process to **test** the validity of their design and, after iteration, **deliver** the final CT tool.

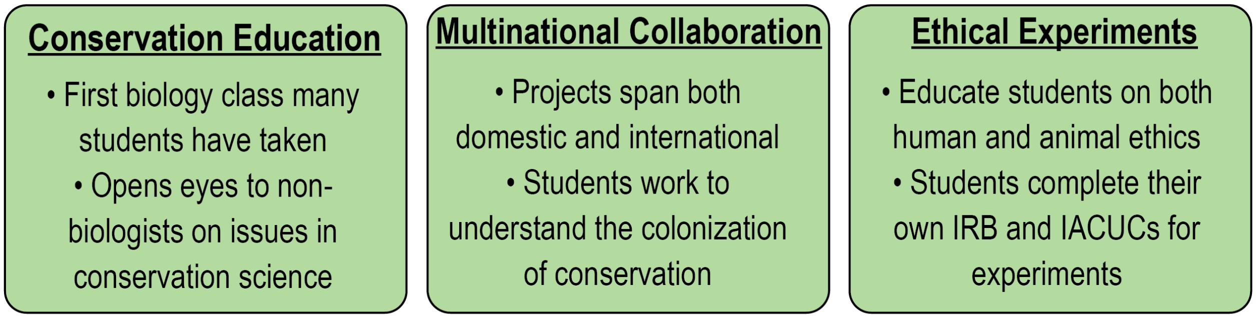

Figure 2. Three pillars of the framework of a successful conservation technology course for engineers.

The framework of the course relies heavily on conservation education, project partner collaborators, and students engaging in scientific discovery through experiments (**Figure 2**). The course structure uses a traditional lecture format for the first 5 weeks to teach students the framework of creating a successful conservation technology artifact. We begin the course by introducing human-centered design as a method for enhancing product reception and success by incorporating the perspectives of intended users throughout the design process. This helps students transition to the fundamental concept of the course, *human-wildlife-centered design,* as a combination of human-centered design and human-wildlife conflict. In conservation biology, human-wildlife conflict is a prevalent challenge with examples ranging from humans invading animals' native habitats to disease transmission of urban wildlife such as coyotes, foxes, and monkeys in dense urban areas. The contents of the lecture-based portion of the course are as follows:

- Introduction to Human-Centered Design, Conservation Technology, and the Sustainable Development Goals
- Human-Centered Design and Context of Use
- Effective Reading, Writing, and Interdisciplinary Teamwork
- Conservation Technology 101 - Biology: Ecology and Behavior
- Conservation Technology 101 - Indigenous Design Solutions
- Team Meetings, Guest Speakers, and Presentations

Once the course fundamentals and **conservation education** have been covered, we form interdisciplinary teams of engineers, biologists, and computer scientists. These teams are paired with conservation leaders for both domestic and international projects to establish **multinational collaborations**. For each project team, students work to incorporate indigenous design into their projects and work to counter the historical colonization of conservation that has occurred in the CT space[10]. Finally, students work to conduct or inform **ethical experiments** by working on IACUC and/or IRB protocols. The course spans several semesters, and we allow course alumni to serve as peer-mentors to new members of CT projects. The peer-support aspect is a cornerstone of the successful VIP program at Georgia Tech[11]. In active learning environments that include an element of research, Lopatto found that peer-mentoring benefits both mentors and mentees[12]. Lopatto found that almost 80% of undergraduate students who do research with other undergraduate peers have an enhanced research experience at a moderate or significant rate. The interdisciplinary and multi-semester nature of the conservation projects has helped engineers apply their skills to sustainable developmental practices.

Course Learning Outcomes

In the Tech4Wildlife course, we currently utilize the following learning outcomes for a novice in conservation technology:

- Identify examples of conservation technology & human-centered design
- Review and critique current CT projects using human-centered design principles
- Design and submit an interdisciplinary CT project to an online digital maker space
- Analyze current CT practices including tracking, monitoring, software, and hardware technologies used in the industry
- Explain the historical issues in working on conservation technology and become an advocate for utilizing human-centered design to help wildlife and the environment
- Communicate with international leaders in species conservation

Course Structure Overview

The course was first taught during the Fall 2019 semester at Georgia Tech and student enrollment has steadily increased over the past four semesters to 20 students every semester. The Vertically Integrated Project structure allows students to take the course first as sophomores for one credit, and as they continue to participate, they can take two or three credit options to increase their involvement in the projects. Teams in the course are interdisciplinary and are made up of 3-5 students comprised of engineers, biologists, and computer scientists from varying grade levels. At the beginning of each semester, new students listen to descriptions of current projects and indicate their preferences for the project team that interests them. Each existing team concurrently indicates to the instructor what majors/types of help their project needs for the upcoming semester. The instructor then tries to match new student interests with existing team needs. This structure allows for both student voice and choice, continual evolution of the projects over time as new team members join, and the opportunity for technological pivots to occur within existing teams. We currently have a high student retention rate with 96% of students continuing into the second semester of the course and 90% of students continuing into the third semester of the course. In the next section, we provide an example of a team project to highlight the real-world, interdisciplinary nature of CT projects.

Project Case Study: Urban Fox Vaccination

In focusing on a case study of an interdisciplinary project between engineers and scientists, we will discuss an ongoing project that began in Spring of 2020 which focuses on designing technology for urban fox rabies vaccination. Despite the urban placement of Georgia Tech's Atlanta Campus, grey foxes have found ways to remain hidden in the limited green spaces that exist. In 2019, however, their existence became well-known when a rabid fox committed a string of attacks on students. The rabid fox was captured and tested positive for rabies, resulting in the necessary removal of most of the campus' fox population. While the cull removed most of the foxes, later observations confirmed that a small fox population still existed -- either left over from the cull or new campus inhabitants.

Students in our course purchased camera traps (**Figure 3A**) and installed them around campus (**Figure 3B**) to determine the range of the foxes and identify where they were denning on campus more precisely. To increase the likelihood of preservation of campus foxes, the team is now working on using oral rabies vaccines (or rabies biscuits) in a bait-release method. The method of distribution typically used in wildlife management is to distribute large amounts of these biscuits over rural areas by aircraft, which is impossible to do in urban settings[13]. To circumvent this, students are currently designing an automated, bait dispensing feeder that interfaces with the camera traps to bait specific wildlife in a targeted manner. To build a feasible

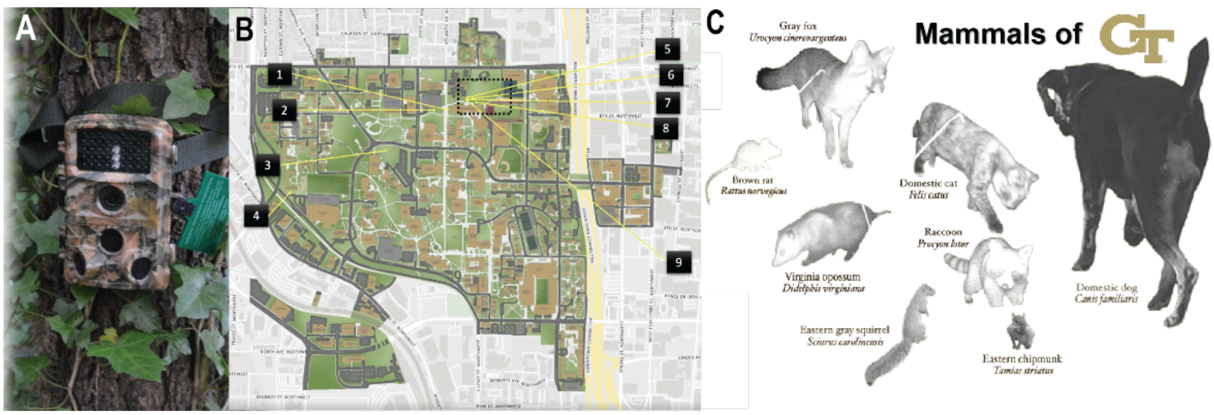

Figure 3. Urban Fox Conservation Technology project. Camera traps (A) were placed around campus in specific locations of heavily forested areas (B) to identify the different urban wildlife on Georgia Tech's campus (C).

device, students need to consider what other types of wildlife would interact with the technology. By working to identify all the different urban mammals at Georgia Tech (**Figure 3C**), students modified their design requirements to ensure that mammals as large as 30 kg domestic dogs will not break the device or interfere with its operation. By placing the biscuit dispensers in key locations around campus, the team hopes that foxes will habituate to the dispenser and voluntarily consume dispensed biscuits. One primary concern is the minimization of consumption by non-target species. In previous bait-station efforts, like the Coyote Lure Operative Device, researchers have used containers that can only be opened by certain animals[7]. However, these solutions were single use.

In favor of a multi-use solution, the team is developing a computer vision model to identify the target species. They aim to integrate this model to trigger the dispensing of biscuits only when a grey fox is present. A future challenge is to define the monitoring method necessary to determine if a satisfactory number of foxes is using (and continues to use) the bait-dispensing system. To address this, the team is also looking into methods of recognizing individuals who access the bait using biological markers and/or computer vision[14].

Student Outcomes from Fox Project

In reflecting on the student learning outcomes described previously, the interdisciplinary team of students including engineers, computer scientists, and biologists worked on identifying different types of conservation technology and human-centered design challenges in the field of wildlife vaccination. The students analyzed different types of smart and intelligent dog feeders as well as automatic bird feeders that failed to consider the non-target wildlife. In the case of the fox device, raccoons will attempt to break and enter any technology around them. Students analyzed the various failure modes that can take place across disciplines—software logic, bugs, and edge cases (computing), mechanical failures, and biological considerations and behavior models. Discussing these different designs and possible failure modes with leaders in urban carnivore disease management and fox behavior provided teams with valuable insights from conservationists and a deeper appreciation for the nuances of implementing engineering design in ecological contexts.

In terms of the UN Sustainable Development Goals, the students in this project are working on 'life on land' and 'sustainable cities and communities.' These SDGs are being integrated into the course curriculum and student experience while utilizing the engineering design process, following the scientific method, and working with various project partners to develop a successful interdisciplinary project.

Future Work

We have run this course for the last five semesters, experimenting with different course materials and encountering challenges with having an online, project-based course during the pandemic. We are currently working on identifying the critical components that make the overall course successful. We are surveying current and past student participants as well as conducting formalized interviews with students to gauge the best ways to learn conservation technology. We are working to use this data to successfully develop and distribute an online toolkit for other universities to use to create a sophomore-level engineering course for an introduction to conservation technology. This course would be accessible to interdisciplinary engineering students and allow them to apply their first year of engineering design tools to work towards using indigenous design, and ultimately, create conservation tools to end wildlife extinction.

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