Integration of Ethics-Focused Modules into the Steps of the Engineering Design Process

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Abstract

Despite a consensus that engineering students need exposure to ethical decision-making, the degree to which ethics are incorporated into undergraduate curricula remains varied. At Duke University, the engineering departments use a patchwork approach to ethics education, although all students are exposed to ethics in the capstone design course. A new, required first-year design course (EGR 101) for all incoming engineering students presented an opportunity to strengthen students’ ability to recognize ethical and professional responsibilities and to make informed judgments.

EGR 101 is a project-based design course in which student teams are matched with clients in the community to solve an identified problem. Through the work of creating the solutions to these problems, the teams learn about and apply the engineering design process. The design process consists of seven steps: clarifying the team assignment, understanding the problem, defining design criteria, brainstorming solutions, evaluating solutions, prototyping, and testing. Steps in the design process are taught using a flipped classroom method, in which students watch videos detailing the process prior to class. Then, in class, students complete short in-class activities before applying that knowledge to their team’s design challenge.

To incorporate engineering ethics into EGR 101, a joint faculty and student team with expertise in engineering and ethics developed the described materials. After establishing learning outcomes, the team targeted different steps of the engineering design process to situate ethical discussions. The team utilized the very same design process to develop course modules that would achieve these learning outcomes. Ultimately, the team created four engineering ethics modules that include videos and short in-class activities. Implemented in Fall 2020, the modules correspond with and are embedded within the four steps of the engineering design process:

1. **Systems Mapping.** Students learn to identify the people, societal issues, and materials that are integral to the assigned team project’s problem space. Through drawing a systems map, students analyze how their project and its intended goal connect to the world around them.

2. **Pairwise Comparison Chart Activity.** Students assume the role of various stakeholders (those invested in the project in some way) to complete a pairwise comparison chart, thus simulating how different stakeholders make trade-offs when determining important design criteria.

3. **Testing Game Show.** As students test their own products, the entire class is brought together to compete in an interactive, game-show style activity about the ethics of product testing. Then, students design testing plans for their project that are both effective and consider related ethical questions.

4. **Game of Life Cycle.** Students engage in a Life Cycle carnival game in which teams rotate through five stations of activities. These stations have been designed to teach and to encourage thoughtful discussions about the ethical and environmental implications of the materials that students used in their design solution.
Achievement of these goals was measured using an IRB-approved pre/post study, which recognized that each student would enter the course at a different point of ethical awareness. The assessment questionnaire was based on a combination of the Moral Foundations Questionnaire (MFQ) [1] and a novel instrument focused on the intersection of technology and ethics developed by faculty at Duke University. With data collected in Fall 2020, we analyzed student survey data and found few significant results. In summary, the suite of developed modules that are embedded into the first-year engineering design course should lead to the development of an ethical mindset at the outset of students’ engineering education.

**Overview of Ethics Education in Engineering**

Despite a consensus that ethics is an important topic for engineering students, its incorporation into undergraduate courses remains mixed [2] [3] [4]. Currently, the ABET Student Outcome #4 in Criterion 3 requires that graduates have “an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts” [5]. Since ABET 2000, the language around ethics in Criterion 3 has been vague, with the intention to give departments and programs flexibility to implement ethical content as they see fit. However, the nonspecific language may have contributed to uncertainty about the role of ethics in engineering education, yielding uneven educational outcomes in the first ten years of its implementation [6]. For many programs, Criterion 3 remains one of the most challenging elements to effectively integrate into engineering curricula [7].

The apparent difficulties of incorporating ethics into engineering curricula make it no less of a worthy effort. It is important to include ethics in engineering education because engineers shape the built and digital world as we know it. Unlike many formula-driven, technical courses, ethical thought and action require evaluating issues whose importance may change with context [4] [8]. Disappointing performance on the Ethics section of the Fundamental Engineering exam demonstrates the failure of some current engineering programs to inculcate ethical thinking in the minds of engineering students [9]. In this section, we offer a very brief overview of some important works and trends in the field.

When engineering courses feature ethics, they typically rely on strictly philosophical or professional approaches to engineering ethics [8]. Our team’s survey of available courses in engineering programs suggests that many employ textbooks (e.g. [10] [11] [12]) and the “big three” ethical frameworks of deontology, consequentialism, and virtue ethics to ground students’ understanding of ethics. Recently, some philosophers have challenged the idea of the straightforward application of ethical theory in engineering education, arguing that formal discussion of abstract moral theories may be a less effective approach in such an applied field. Indeed, if engineering students fail to see the relevance of the ethical training they receive, ethics education may actually become counter-productive [13] [14]. Alternatively, some engineering programs take a more compliance-oriented approach, solely framing engineering ethics around engineering codes of ethics [4]. However, such an approach narrows the scope of concern to only what is currently enshrined in professional engineering codes of conduct, leaving out potentially important considerations such as sustainability or social justice [15].
Teaching ethics in the context of design offers an alternative to purely philosophical or professional approaches. Research has shown that the most effective pedagogies often mirror the future work environment and require complex thinking [16]. Contemporary design practices, including participatory design, human-centered design, and co-design, respectively, are often structured around ethical concepts such as virtue, alterity (the assumption of the existence of an alternative way of thinking), and pragmatist ethics [17]. Indeed, one designer noted “when we open the ‘black boxes’ of design practices, we find them filled with ethics,” suggesting that design practitioners should make explicit the inherent ethical qualities of their practices [17].

Given that design and ethics are natural cognates, some have suggested that the most promising methods for teaching engineering ethics incorporate interactive design and service-learning projects [3] [16] [18]. Placing a reinvigorated emphasis on design can effectively combine the relative strengths of professional and philosophical approaches to engineering ethics education while minimizing the weaknesses of either approach. As Genova and Gonzalez argue, “the analogy between ethical problems and design problems is also very much connected with virtue ethics and the proper reflection on the nature of engineering as a human activity” [19]. This is further compounded by Roeser’s observation that design is not value-free; thus, design forces engineering students to confront their values [20].

Also discussed in the literature is the timing and frequency with which students should be challenged with ethical situations within their engineering course of study. In some programs, the discussion of ethics has been relegated to a capstone design course with a “one and done” approach. While we agree that capstone design courses offer a powerful opportunity to strengthen engineering ethics education, we support the claim that one exposure to ethical thinking in capstone design is insufficient. Instead, ethics education should be integrated throughout the curriculum and should engage students through different methods. For example, to diversify the types of learning methods, the use of interactive games enables students to progress beyond the regurgitation of ethical concepts, forcing them to practice these ethical principles [21].

**Ethics Education in Duke Engineering & the Scaffolding Ethics Team**

Like many schools, ethics is consistently incorporated into senior design courses in the Pratt School of Engineering at Duke University. While these courses place a notable emphasis on ethics, the leadership and instructors within the first-year program felt strongly that attention to engineering ethics should be incorporated at the outset of a student’s academic career. In addition, many of the instructors in the first-year design course noted regular discussions with students about tradeoffs and ethical dilemmas embedded in their project. Thus, the goal of the Scaffolding Ethics project was to more systematically incorporate ethical considerations into the first-year engineering design course.

During the academic year 2019-2020, we established a research and design team within Duke University’s Bass Connection program. The Scaffolding Ethics team, composed of three undergraduates and three professors from the Pratt School of Engineering and the Kenan Institute for Ethics, met each week to determine and execute how ethics could be embedded within the first-year engineering design course at Duke University.
Framework of First-Year Design Course

Introduction to Engineering Design and Communication (EGR 101) is a project-based design course, in which teams are matched with community partners to solve a problem (Table 1). In creating the solutions to these problems and building prototypes, the teams learn about and apply the engineering design process (EDP) [22] [23]. Steps in the design process are taught using a flipped classroom method, where students watch videos detailing the process prior to class. Then, in class, students complete short in-class activities before applying that knowledge to their team’s semester-long design challenge. Students complete assignments at every step of the EDP. At the end of the semester, most teams have to-scale, functional prototypes.

Table 1. Sample Design Projects

<table>
<thead>
<tr>
<th>Project Client</th>
<th>Project Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duke Lemur Center</td>
<td>Develop an enrichment device for the aye-aye lemurs that delivers a small amount of food</td>
</tr>
<tr>
<td>Dr. S. Rent</td>
<td>Develop a device that simultaneously measures the temperature of five newborns placed in one crib (for use in Ethiopia)</td>
</tr>
<tr>
<td>X-Prize Team</td>
<td>Design a drone that can attach to a tree branch to deliver a camera</td>
</tr>
<tr>
<td>Museum of Life &amp; Science</td>
<td>Design a device that randomly delivers food to skunks in their enclosure</td>
</tr>
<tr>
<td>Bridge2Sports</td>
<td>Develop an easy method for wheelchair users to pack basketball wheelchairs in a trailer</td>
</tr>
<tr>
<td>C. McMillan</td>
<td>Develop an app that alerts students that music practice rooms are available</td>
</tr>
<tr>
<td>City of Durham Transport Dept</td>
<td>Design a bicycle path that connects a green beltline to a road</td>
</tr>
</tbody>
</table>

The EDP used to frame EGR 101 consists of seven steps: clarifying the team assignment, understanding the problem, defining design criteria, brainstorming solutions, evaluating solutions, prototyping, and testing (Figure 1). Because of the emphasis within the course on the design process and that each team works on a different client-based project, we created educational materials that targeted the different steps of the EDP to situate ethical discussions throughout the process and course. Due to the varied nature of the projects, some projects more readily suggest a foundation for ethical discussions than others.

Figure 1. Engineering Design Process
Design Methodology

We followed the engineering design process (Figure 1), as a means to develop the educational materials. Steps 1 and 2 included research, in which we explored the current literature surrounding ethics within engineering, examined the current learning experience within the course, and measured the attitudes of current engineering students within the undergraduate program at Duke with respect to ethics. As our team began the Scaffolding Ethics project, we conducted online research and spoke to educators in engineering programs across the United States to see how they implement ethics within their curricula.

Our team consulted with professors at other institutions, including the University of Virginia, Olin College, and Bucknell University, who shared their own attempts at incorporating ethics within engineering curricula. Our research suggests that many engineering schools do not incorporate ethics explicitly into their first-year courses, although several are beginning to do so [18] [24]. Instead, most schools embed ethics in capstone design. While some offer a seminar that focuses on ethics or feature it more prominently, these are not typically required for graduation. Through interviews, we learned that faculty frequently teach engineering ethics using case studies and reflective essays.

However, the efforts of some engineering schools mark a shift towards novel engineering ethics education. Notably, Bucknell heavily emphasizes ethics within their engineering curriculum, offering classes from the 200 to 400 level that feature ethics in their syllabi [25]. Additionally, design schools also often dedicate considerable effort to the topic of ethical design. At the Carnegie Mellon School of Design, students can focus on different design pathways, such as Design for Service (which looks for needs within particular contexts), or Design for Social Innovation (which looks to leverage or amplify existing resources) [26].

To prepare ourselves, we studied traditional ethics philosophers, such as Kant and Mill, and read case studies focused on engineering ethics. Using this base knowledge, we then interviewed former EGR 101 students and instructors to identify general attitudes towards ethics and design. Upon synthesizing the information that the Scaffolding Ethics team collected, we defined student learning outcomes related to ethical issues in EGR 101 as:

- Understand what “ethics” is and explain how it is generally relevant to engineering,
- Use ethical tools to interpret a problem and identify dilemmas,
- Connect design ideas to their social and ethical consequences,
- Justify a design decision related to ethics, and
- Recognize the value of responsibility as a result of the design process.

In order to determine how we would design course modules that would achieve these learning outcomes, our team continued on the design process with Steps 4, 5 and 6. We brainstormed and analyzed various ideas, compared different approaches using matrices, sought feedback within the Duke community, and continued to iterate. Ultimately, we created four modules that corresponded with activities at various stages of the engineering process. Our goal was to supplement learning, not disrupt it, and we therefore designed the modules to seamlessly connect with the activities that students would already be doing within the course.
Developed Engineering Ethics Modules

The final ethics modules for EGR 101 were embedded within the EDP in Understanding the Problem/Context (step 2), Define Design Criteria (step 3), Prototyping (Step 6) and Testing (Step 7). These modules, included in Appendix A, focused on Systems Mapping, Pairwise Chart Comparison, Ethics of Testing, and Life Cycle Analysis, respectively. For each of the modules, students apply a set of questions to their team’s unique design project. As such, the teams discuss the ethical implications and values related to their design project and the impact these discussions have on decisions within their project.

For all modules, we created a short video to introduce key ideas, vocabulary, and ethical principles. Students watch these videos before class, as they do with the other videos for EGR 101. In class, following a few short comments from the instructor, students complete a written in-class exercise with focused questions. The Testing Game Show module has an additional web-based game that the whole class plays together.

1. **Systems Mapping (step 2 of EDP)**. Students learn to identify the people, societal issues, and materials involved within their assigned team project’s “problem space.” Specifically, students develop nodes – actors, contexts and objects – that are associated with their design challenge. Students then connect these nodes using lines, which represent connections. Within a team, students compare their systems maps and reflect on them. By leveraging the systems mapping technique, which involves physical drawing and mapping of both concrete and abstract ideas, students are creatively encouraged to analyze how their project and its intended goal are interconnected with the surrounding world.

2. **Pairwise Comparison Chart (PCC) Activity (step 3 of EDP)**. Students revisit their design criteria and reexamine them through different lenses. By watching a video that captures an ethical dilemma faced by a previous team within the course, students learn how tradeoffs exist within different rankings of design criteria. During the in-class exercise, each student on a team adopts a different stakeholder role (e.g., user, regulator, environmental activist) and completes a PCC, a chart used to rank the importance of various design criteria for a project. Then, each team engages in a guided discussion about trade-offs in their design criteria and resolve any emerged conflicts as a team.

3. **Testing Game Show (step 7 of EDP)**. The entire class is brought together to compete in an interactive, game-show style activity about the ethics of product testing. Twenty questions are run using Kahoot!. Afterwards, students learn how testing can affect vulnerable populations, the circumstances that require IRB approval, and how to design testing plans that are both effective and consider ethical questions. Specifically, they are challenged to reflect on how likely users of the device will test the product, what part of their solution is most likely going to fail, and what is a sound number of repeated tests to ensure efficacy and safety.

4. **Game of Life Cycle (step 6, including iterations, of EDP)**. In the last module, students engage in a Life Cycle “carnival” game in which teams rotate through five stations of activities. These stations have been designed to teach and to encourage thoughtful
discussions about the product life cycle, a high-level concept more deeply explained in upper-level courses. The product life cycle is a tool that allows designers to understand how their product will be built, assembled, packaged, shipped, used, and then disposed of or reused. In this module, students learn to take the view of different stakeholders while performing a skit about a simulated EGR 101 project. They complete a “choose your own adventure” game to compare the utility and environmental impact of different materials for each step of creating a handwashing station. Finally, students hold a “funeral” for the device that they created to think about how their product will be disposed, recycled, or reused. Scheduled at the end of class, the activities are fun and engaging while teaching critical awareness skills.

Implementation of Developed Materials

In conjunction with the EGR 101 instructor in spring 2020, we piloted the Systems Mapping and PCC activity in one section. The final two modules were not piloted that semester, due to remote classes during the COVID-19 pandemic. In fall 2020, we piloted the Systems Mapping, PCC, and Testing Game Show in most of the nine in-person and two on-line sections of EGR 101. A few sections piloted some activities of the Game of Life Cycle, and no sections completed the activity fully (due to both time and social distancing restrictions).

The teaching team relayed this important feedback:

- The Systems Mapping module was lengthy. As written, some teams spent around 30 minutes on this module. Some instructors were not comfortable with this length of time relative to the time dedicated to other activities during that class period.
- The Systems Mapping module generated very thoughtful discussions for some teams, and rather surface-level discussions for other teams. Some teams drew elaborate and unique systems maps, which precipitated new insights into the complexity of their problem, its environment, and potential users. Some teams also chose to not fully engage in the activity, despite the encouragement of faculty and TAs who circulated through the instructional space. In addition, some problems were less obviously complicated from an ethical perspective.
- The PCC module was the favorite new in-class activity, as rated by instructors and students. Almost all teams had lively debates, as they represented different stakeholders. The exercise was easy to understand and well-integrated into the course assignments.
- The Kahoot! activity in the Testing Game Show module was very well received. Students danced and nodded their heads to the music throughout the 20 questions. There was a competitive atmosphere in most EGR 101 sections, and the students had fun.
- The written, in-class exercise developed to extend conversations around Testing was largely ignored. By this time of the semester, students were iteratively prototyping, and students were not interested in taking time away from that work to complete a thoughtful module centered on their testing plan.
- The few modules of the Game of Life-Cycle that were tested were well received. In particular, teams discussed how including the design criteria of sustainability would have affected their prototyping process and final solution. In particular, teams had many reflective discussions regarding use (and waste) of prototyping materials.
Evaluation of Developed Materials

The goal of the assessment was to measure changes in their ethical awareness. Specifically, the research question was:

- How did participation in EGR101, including the four developed ethics modules, affect students’ ethical awareness?

The achievement of these goals was measured using a pre/post study, with the recognition that each student would enter the course at a different point of ethical awareness. Given the difficulty of directly measuring the students learning outcomes, we chose to use established surveys.

The assessment questionnaire is based on a combination of the Moral Foundations Questionnaire (MFQ) [1] and a novel instrument developed by faculty at Duke University. The MFQ inventories participants’ adherence to five different foundational moral categories: care/harm; fairness/reciprocity; in-group/loyalty; authority/respect; and purity/sanctity. The MFQ can be useful in comparing across populations, ranging from political identity [27], professional identity [28], and across national borders [29]. Students selected a relevance of a consideration in deciding whether something was right or wrong using a six-point Likert scale, which ranged from not at all relevant to extremely relevant. Seventeen questions from the MFQ were included, as shown in Appendix B.

In addition to the general insights provided by the MFQ inventory, we were interested in assessing how students’ attitudes towards ethical issues in engineering, design, and technology might change over the course of the term. This novel battery of questions was developed by colleagues (Amber Diaz Pearson, Stacy Tantum) at Duke University as a part of a larger effort to measure ethical awareness. This instrument asked more practical questions around safety, design decisions, regulations, etc. Thirty questions were sourced from this survey and are found in Appendix B. Students selected a level of agreement using a six-point Likert scale, which ranged from strongly disagree to strongly agree. In all, the instrument consisted of 47 multiple choice questions and took ~10 min to complete. The survey was conducted under the Duke University approved IRB Protocol 2021-0134.

We recognize that other changes may be occurring during a student’s first year on campus, although these are factors that cannot be controlled. The Fall 2020 semester in which this data was collected was also fraught with complexity due to the pandemic. While most students in EGR 101 continued to meet in-person and the same content was covered in the class, the schedule differed slightly and the course accepted fewer client-based problems. Finally, there were delays in receiving the IRB. Thus, the pre-survey was released the same week as the first module, the Systems Mapping module. Finally, the last module, the Game of Life Cycle, was pushed to the final exam period, which was after some students completed the post-survey.

With ~300 students in EGR 101, 85 paired (pre-/post-) data sets were collected in Fall 2020 from students who consented for their responses to be used in the analysis. Data was analyzed using a two-tailed, paired sample t-test, with an alpha value of 0.05 [30].

Considering the 47 questions in the survey, only seven had significant differences between the pre- and post-survey administrations (Table 2). Of these seven, none were from the MFQ
questions in the survey, whereas all seven were from the technology survey. Given that 40 of the 47 questions had no significant difference, our overall conclusion is that the ethics modules as deployed in EGR 101 in Fall 2020 did not make a significant difference in terms of ethical awareness.

Table 2. Questions with significant differences between the pre- and post-surveys. Average pre- and post-survey values are given, based on their 1-6 scale. Significant differences are noted with a positive or negative direction.

<table>
<thead>
<tr>
<th>Question</th>
<th>Pre-</th>
<th>Post-</th>
<th>Significant?</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  The most important consideration for an engineer or developer is that a product meets the design criteria.</td>
<td>5.16</td>
<td>4.66</td>
<td>YES</td>
<td>NEG</td>
</tr>
<tr>
<td>2  If something goes wrong in a project, everyone involved is equally responsible.</td>
<td>3.93</td>
<td>4.21</td>
<td>YES</td>
<td>POS</td>
</tr>
<tr>
<td>8  Engineers should consider all possible use-cases and consequences before releasing a product.</td>
<td>5.56</td>
<td>5.35</td>
<td>YES</td>
<td>NEG</td>
</tr>
<tr>
<td>12 Significant tradeoffs are necessary in the design of any product.</td>
<td>4.05</td>
<td>4.28</td>
<td>YES</td>
<td>POS</td>
</tr>
<tr>
<td>13 If someone is aware of an unethical practice at their company and does not speak out, they are also doing something unethical.</td>
<td>4.95</td>
<td>4.69</td>
<td>YES</td>
<td>NEG</td>
</tr>
<tr>
<td>14 Too much regulation makes it hard for innovative ideas to get off the ground.</td>
<td>4.46</td>
<td>4.22</td>
<td>YES</td>
<td>NEG</td>
</tr>
<tr>
<td>28 My country should use technological developments to gain an economic advantage in the global market.</td>
<td>4.4</td>
<td>4.13</td>
<td>YES</td>
<td>NEG</td>
</tr>
</tbody>
</table>

Three of the developed ethics modules had students discuss or recall their design criteria. Table 3 shows the students’ responses for the four questions in the survey related specifically to design criteria. Here, we observe some movement of student thinking. Students realized that there are tradeoffs among design criteria (Question #12). Students also recognized that while design criteria are important, other factors play a role in development of a product (Question #1). These results are encouraging since the ethical discussions around design criteria were prominent in the course.

Table 3. Questions related to design criteria. Average pre- and post-survey values are given, based on their 1-6 scale. Significant differences are noted with a positive or negative direction.

<table>
<thead>
<tr>
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<th>Pre-</th>
<th>Post-</th>
<th>Significant?</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  The most important consideration for an engineer or developer is that a product meets the design criteria.</td>
<td>5.16</td>
<td>4.66</td>
<td>YES</td>
<td>NEG</td>
</tr>
<tr>
<td>7  It is permissible if some people are harmed as long as a product meets the design criteria.</td>
<td>1.69</td>
<td>1.81</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>12 Significant tradeoffs are necessary in the design of any product.</td>
<td>4.05</td>
<td>4.28</td>
<td>YES</td>
<td>POS</td>
</tr>
<tr>
<td>30 It is never permissible to release a product that may not satisfy all safety criteria.</td>
<td>4.8</td>
<td>4.91</td>
<td>NO</td>
<td></td>
</tr>
</tbody>
</table>

Some significant results in Table 1 were unexpected. In the Testing module, students were asked to consider the possibility of testing with likely users, which aspects of their product were most likely to fail, representative conditions for testing, and realistic numbers of repeated tests.
Disappointingly, the response to Question #8 dropped significantly, indicating that students were less committed to considering possible use-cases and consequences before releasing a product. While teamwork and communication were emphasized in the class, the ethical dimensions of these were not (Questions #2, #13). In EGR 101, there was no discussion on regulations (Question #14) or global markets (Question #28).

Reflections and Next Steps

Overall, the implementation of the ethics modules went as well as could be expected, given the difficult Fall 2020 semester. Given the feedback above, we expect to make a few changes in fall 2021, including:

- Students will complete Steps 1-5 of the Systems Mapping module prior to coming to class. The remainder of the module will be completed in class, as a group.
- Aspects of the Game of Life Cycle may be implemented earlier in the semester, so that the students become more aware of materials use.
- The pre-survey will be administered the first week of class, and the post-survey will be administered after all ethics-related modules are completed.
- The Testing module will be reconsidered to more appropriately integrate the assignment that captures the team’s testing plans.

The greatest strength of the developed materials was that they were designed to be situated within the teams’ semester-long, client-based project. In this way, students were thinking about ethical issues in the context of their specific project [3] [16] [17] [18] [20]. With more thoughtful integration of these modules into team’s specific work, we may be able to increase the effectiveness of the exercises and increase the ethical awareness of students.

Moving forward, we are working with the Pratt School of Engineering to administer this survey throughout students’ four years. In this way, we may be able to see impacts of this and other emerging efforts on students’ ethical mindset.

Conclusion

In summary, the suite of developed modules that are embedded into the first-year engineering design course should begin to cultivate an ethical mindset at the outset of students’ engineering education. Through the modules, students are exposed to new tools that help them think more critically about their design decisions and explore the impact their designs could make on the world. While our evaluation of the developed materials indicated a small, if mixed, effect on shifts in student mindset, the modules were successfully integrated with student projects – allowing for ethical considerations within specific projects. Moving forward, the suite of modules should foster a sense of responsibility among the students of EGR 101 and empower engineering students with an ethical mindset to help them one day become ethical engineers.
Appendix A

Systems Mapping
Video: https://www.youtube.com/watch?v=Y_JiNKUl4H0&list=PLjrhwkAmyJgJy4JaVB56Oq7X46xh7Zy&index=6
Quiz: On course learning management system
ICE: Below, labelled “In-Class Exercise, Step 2: Understanding the Problem and Context”

Pairwise Comparison Chart (PCC) Activity
Video: https://www.youtube.com/watch?v=YEl5geLIR74&list=PLjrhwkAmyYj21YoMkjs4BLCyZgZw3w_-&index=6
Quiz: On course learning management system
ICE: Below, labelled “In-Class Exercise, STEP 3B: Pairwise Comparison Charts”

Testing Game Show
Video: No new video created.
Kahoot: Below, labelled “Kahoot Questions, STEP 7B: Testing”
ICE: Below, labelled “In-Class Exercise, STEP 7B: Testing”

Game of Life Cycle
Video: https://www.youtube.com/watch?v=ScY_Yb1V8AY
(Note: this was produced by GCSE Chemistry.)
Quiz: On course learning management system
ICE: Below, labelled “In-Class Exercise LCA #0, Life Cycle Analysis Carnival Intro,” “In-Class Exercise LCA #1, Skit,” “In-Class Exercise LCA #2, Flip Card Game,” “In-Class Exercise LCA #3, BYOA Handwashing Station,” “In-Class Exercise LCA #4, Line Up! Line Up!,” “In-Class Exercise LCA #5, Device Funeral,” and “In-Class Exercise LCA #6, LCA Carnival Wrap-up”
In-Class Exercise  Step 2: Understanding the Problem and Context

Introduction

Systems Mapping is a tool that allows teams to visualize the dynamics and connections within systems. By drawing out who/what is involved within the problem space and how those entities are involved, engineering teams can better:

1. Understand how individuals and/or organizations are important toward accomplishing goals.
2. Recognize the political, social, environmental, and economic realities that play a role in the project’s problem space.
3. Identify tensions created by the project, both direct and indirect.

A systems map is comprised of nodes and connections. The nodes are the actors, context, and objects that exist within your problem space. The relationship between one node and another is shown by using connections.

![Node Connection Node]

For systems maps, teams will have three categories of nodes, each represented by a different shape:

- **Actors** (circles): These are the individuals, groups, and organizations (such as your team, your client, government agencies, non-profits, donors, etc.) who are players within your problem space. These may include, but are not limited to:
  - Those responsible for creating the problem
  - Those impacted by the problem
  - Those who are trying to address the problem
  - Those with major influence over the problem space

- **Context** (squares): These are the political, social, or economic realities affecting your problem space. This includes behaviors, issues, norms, values, preferences, and actions. These may include, but are not limited to:
  - Income levels
  - Community support
  - Inclusion around disabilities
  - Regulations

- **Objects** (triangles): These are the technologies, resources, and items that play a significant role in your problem space. These may include, but are not limited to:
  - The product that an EGR 101 team designs
  - Natural resources
  - Labor
  - Academic research (or lack thereof)
  - Internet connectivity

The connections between nodes will be drawn using directional arrows. Be thoughtful when drawing the connections! The goal is create quality connections, not just quantity of connections. The directionality of the line, indicated by one or two arrows, provides more information on the relationship between nodes (i.e., Is the relationship mutual? Is one entity only providing for the other?).
Task

*NOTE: Steps 1-5 below are to be done individually*

**Step 1:** Think about (or reread) your project prompt. What problem or issue are you tackling? Think about the location or space where the problem exists.

**Step 2:** Create a list of actor items. Include all members of the user-client-designer triangle.

**Step 3:** Create a list of context items.

**Step 4:** Create a list of object items.

**Step 5:** Draw a systems map. Include the actors, context, and objects on the systems map and draw connections. Remember that actors are circles, contexts are squares, and objects are triangles. Use directional arrows to connect nodes.
Step 6: Briefly compare your systems map with others on your team. How are they similar? How are they different?

Step 7: With your team, discuss and make notes on the questions below. Refer to specific points on the systems map to explain your answers.

A. Consider actors, contexts, and objects. Which of the nodes were on a majority of the concept maps? Which were only on a few?

B. How are the actors, contexts, and objects impacted by the problem? How are the actors, contexts, and objects impacted by a possible solution?

C. Which node(s) had the most connections on each map? What does this tell us about potential tensions between nodes that exist within the problem space?

D. What does this systems map tell you about the relationships, obligations, and ethical responsibilities above and beyond your “Need to Know” list?
In-Class Exercise   

STEP 3B: Pairwise Comparison Charts

**Introduction**
The purpose of this exercise is to consider the ranking of design criteria from different perspectives and to realize that different stakeholders in your project may value these criteria differently. Each of the roles in this exercise simulate individuals an engineer would need to engage with during the design process. These individuals may have very different priorities and points of view, and as an engineer you must take these different perspectives into account.

To begin, you will list some of your project’s design criteria. Then, you will individually answer a set of questions from the perspective of the role you have been assigned. You will then create your own Pairwise Comparison Chart (PCC) to identify your role’s top priorities. For the second part of the activity, your team will reflect on differences among your PCCs.

**Design Criteria (to be done as a group)**
List five design criteria that will likely be considered for your project:

1. 
2. 
3. 
4. 
5. 

**Roles**
Each team member will be assigned one of the following roles. To assign roles, count off starting at 1. The roles below are associated with a count-off number.  

1, 5. **Client:** The individual who has requested a solution to an identified problem. The written project proposal and notes from the client interview, including desired functions and design criteria for a solution, typically strongly reflect the views of the client.

2, 6. **User:** The individual or group who will use the solution, device or product. The user sometimes has conveyed desired qualities to the client, but sometimes has not.

3. **Designer:** The team applying the engineering design process to the problem.

4. **Regulator:** The outside authority figure that enforces laws and regulations on design solutions.
**PCC for your Role’s Perspective**

On your own, create a PCC that you believe would satisfy the considerations of the role that you have been assigned. While filling out the PCC, consider these questions:

- What design criteria are most important for a person in your role?
- Which criteria are the least important for a person in your role?
- What is the most important function this solution must achieve for it to be viewed as successful by your role, even if it means sacrificing other components?

---

**Team Reflection Questions**

1. What are your top design criteria? Do they differ across the different roles? Why do you think your design criteria differ?
2. Do you believe your client relied on assumptions about users based on their experiences? Has your team spoken directly to users?
3. What tradeoffs were you willing to make in ranking your design criteria? (One common tradeoff is between cost and durability.) What might be some consequences of these tradeoffs?
4. If you were to combine these different perspectives into a “final” PCC, whose point of view would win or lose? Why?
5. What kinds of obligations should an ethical engineer have to stakeholders whose priorities are determined to be less important through the PCC process?
Kahoot Questions

STEP 7B: Testing

1. What is an appropriate method of testing for a phone case that should be "drop test durable"?
   a. Drop off Swift balcony
   b. **Drop off 3 meters**
   c. Drop from top of the Chapel
   d. Drop from waist level

2. A marine research tool has been tested in water 10,000 times and hasn't let water in. Should you conduct other tests?
   a. **Yes**
   b. No

3. How can a team avoid bias in their testing results?
   a. Large sample size
   b. Ask objective questions
   c. Have people outside your team test the device
   d. **All of these**

4. What is a minimum number of tests needed to confirm a less than 1% failure rate?
   a. 20 tests
   b. 100 tests
   c. 1000 tests
   d. 10,000 tests

5. To test your device on human subjects, you don't need IRB approval.
   a. True
   b. **False**

6. You need to understand the risks and benefits of your device before testing it on a vulnerable population.
   a. True
   b. False

7. We’re building a drone for adventure photographers. The drone should be tested in:
   a. Only windy conditions
   b. Only calm conditions
   c. Only in the rain
   d. **None of these**

8. On which population should you test an app to encourage high school dropouts to complete their GED?
   a. College professors that have knowledge of effective learning methods
   b. Current high schoolers to encourage them to continue their education
   c. **High school dropouts to motivate them to complete their education**
   d. All of these

9. Which of the following projects definitely require IRB approval?
   a. A project that requires collection of quantitative data
   b. **A project that requires human testing**
   c. A project that could benefit others if published
   d. All of the above

10. Which is an example of durability testing for a device that is used to filter water contaminants?
    a. **Testing the battery life of the product**
    b. Measuring the efficacy of the product (% water contamination before and after use)
c. Seeing the effect of the product on organisms in water
d. None of these

11. Which of the following is an appropriate question to ask while testing?
   a. Do you think this product is too heavy?
   b. Do you think this product will benefit the population in need?
   c. **How would you rate the efficacy of this product?**
   d. This product is safe, right?

12. What is most important when designing your tests?
   a. **The well-being of your users**
   b. Your grade
   c. How long your product lasts
   d. Client approval
In-Class Exercise

STEP 7B: Testing

Task

The decisions you make about testing have ethical implications. Some questions that need to be carefully considered are: who you test, how much you test, and the conditions under which you test. Please thoughtfully consider the following questions to reflect as you develop your testing plan. Select design criteria that are sufficiently complicated when considering the questions. If one of the questions below is not relevant to your project, you may skip it.

1. First, focus on the complexity of who is involved in tests.
   - Who are potential users?
   - Can you test directly with this group? Why or why not? What constraints are present?
   - Sometimes students ask fellow EGR 101 students to test their product. How similar or not are EGR 101 students to your potential users? Specifically identify similarities and differences.
   - Are your potential users from a vulnerable population (person with a disability, children, etc.)? How might your testing plan need to reflect this?

2. Consider the durability of your product.
   - Brainstorm all the ways in which your device could fail.
   - Which are the most likely to fail?
   - Develop a testing plan for durability for two of these likely failure modes.
3. This exercise focuses on how realistic the conditions are when you test. Pick three of your design criteria and complete the chart.

<table>
<thead>
<tr>
<th>Design criteria</th>
<th>Describe test</th>
<th>Given the users and their environment, what are representative conditions under which you should conduct testing?</th>
<th>Under what conditions will you likely test in EGR 101?</th>
<th>What are the limitations of your expected testing results?</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>

4. This exercise focuses on how many tests are needed. Pick three of your design criteria and complete the chart.

<table>
<thead>
<tr>
<th>Design criteria</th>
<th>Describe test</th>
<th>Given the potential use of the product, how many times should you test?</th>
<th>In EGR 101, what is a realistic number of tests for your team to do?</th>
<th>What are the limitations of your expected testing results?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>
Introduction
Welcome to the EGR 101 Carnival! Today, your team will be exploring sustainability and the environmental impacts of the design process. “Sustainable” design does not only consider the immediate problem and its local context, but rather how the problem can be solved over a long period of time within a global context.

When discussing sustainable design, engineers must consider a wide variety of factors related to the materials used within a product. These factors include longevity of the materials, the supply chains through which the materials are sourced, cost, reusability, and more. Engineers often use the formal process of a Life Cycle Analysis (LCA) to quantitatively evaluate a product, its impact on the environment, and its sustainability.

To begin today’s event, please gather with your design team. Your instructor has scattered a collection of objects around a large area. When your instructor yells “Go,” use the key below to retrieve the proper types and numbers of objects. The items your team collects should correspond directly to the materials you used to create your own design projects, including prototypes. Place the collected items in a bag or backpack. Carry them with you for the rest of the class period, as you engage in the remaining activities.

<table>
<thead>
<tr>
<th>If your team has used:</th>
<th>Collect:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals, including Arduino and hardware (bolts, nails)</td>
<td>Medicine balls (1 ball)</td>
</tr>
<tr>
<td>Fabrics/textiles</td>
<td>Beach balls (2 balls)</td>
</tr>
<tr>
<td>Foam</td>
<td>Pool noodles (3 noodles)</td>
</tr>
<tr>
<td>Plastics, including 3D printing or acrylic</td>
<td>PLA scrap (1 piece per component of your design that relied upon 3D printing or acrylics. For example, a component could be a 3D printed gear or one side of an acrylic box.)</td>
</tr>
<tr>
<td>PVC</td>
<td>Baseballs (2 balls per meter used)</td>
</tr>
<tr>
<td>Wood</td>
<td>Scrap wood (3 pieces per meter used)</td>
</tr>
</tbody>
</table>

The items that you and your team have collected represent your environmental impact “burden.” Every resource you use in EGR 101, at Duke, and in the broader world plays a role in a massive network of global supply chains. While many of the materials in this class can feel “free” to Duke students, it is important to recognize that every item has both a material and environmental cost. We urge you to consider the impact of your own engineering design process today as you carry these objects you collected – your physical burden – from station to station.
Introduction
A professional engineering team is building a bridge over a stream in a city park. The addition of the bridge will allow individuals from a lower income neighborhood to access recreational areas. Due to city ordinances, the bridge must be made mostly out of wood. However, the choice of wood has raised concerns by some members of the community for its environmental impact. Consider the five stakeholders and their perspectives. Gather five people together and try to resolve this conundrum, with each person maintaining their “character.”

Issue: To meet city ordinances, the bridge needs to be constructed mostly out of wood. Can the stakeholders agree on a forward plan that meets all needs?

Task
Given your role, act out a skit with four others to solve this problem. Be sure to incorporate all your character’s wants and needs when playing your part. It is important to get your role’s most important views across, and tradeoffs/compromises may need to be made.

The roles are below. Each student will be given their own description.

- Commercial forest owner
- Environmentalist
- Engineer
- City planner
- Neighborhood resident
**In-Class Exercise LCA #2  Flip Card Game**

**Introduction**
In EGR 101, many teams use a wide range of materials. Yet, where do these resources come from? An important step while performing a Life Cycle Analysis is determining where materials are sourced, how they are manufactured, and how they are brought together to create a final product.

**Task**
In this activity, you will play the *Life Cycle Material Matching Game* (https://tinyurl.com/egr101matchinggame) individually. The items in this game represent frequently used materials in the POD and Foundry workspaces (e.g., wood). Match the material to the location or process from which it came (e.g., forest). When all members of your team have successfully completed the game, answer the following questions:

1. Were there any card pairs that surprised you? Why?
2. Using the information in this game, where might some of the materials used in your own project come from? Make a list of the materials in your project and where those materials may have been sourced from.
3. A supply chain is defined as a sequence of processes involved in the production and distribution of a product. Using the information in the matching game, what might your final product’s supply chain look like?
In-Class Exercise LCA #3  
BYOA Handwashing Station

**Introduction**
People in low-resource households such as the Aeta Community in Bamban, lack running water and/or access to a clean source of water, making handwashing a difficult process. The Municipality of Bamban is in the province of Tarlac, Philippines. In this community, there is a hand pump station that serves as the only source of water for approximately 30 homes. Residents of the community use old 5 L jugs and small cans, which can be cumbersome and ineffective to transport the water to their homes. Handling of the jugs and cans usually results in recontamination of the hands.

The goal of this project is to build an easy-to-use hand-washing station for low-resource households in the Aeta Community. Water flow from the station should be easily started and stopped, using a mechanism that prevents recontamination of the hands; i.e., the flow start/stop mechanism should not require touching with the hands after washing. The station should be easy to refill with water, assuming that no piped water is available in most locations; i.e., refilling has to be done manually. The station should also have a place to hold soap, and a collection system for the greywater. Ideally, the station should be built with materials available in the Aeta Community. The station should be easy to maintain and repair, as well as very low cost (<$300).

**Task**
The goal of the activity is to create a solution with the minimum points. Points are awarded based on choices that you make between various materials, as well as the cost of those materials. While you play the game, keep track of the following in Table 8.1:

1. What materials you chose for the design
2. How many “setback” slides you see
3. The cost of your choice

Every time you hit a setback, repeat the choice and add a second choice and cost in that step. For example, if you reach a setback while on the Refilling stage, keep your original choice and cost on the table and also add your second choice.
To calculate your final points score, there are three steps:

1. Determine the points score associated with your total cost
2. Determine the points score associated with your total setbacks
3. Determine the points score associated with your materials choices.

### 1. Cost
- If you spent $0 - $100, give yourself 10 points.
- If you spent $100 - $200, give yourself 20 points.
- If you spent $200 - $300, give yourself 30 points.
- If you spent $300+, give yourself 50 points.

### 2. Setbacks

<table>
<thead>
<tr>
<th>Material Chosen (Write the exact choice)</th>
<th>Setback? (Y/N)</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start/stop mechanism</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refilling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soap holder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greywater collection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>---------------</td>
<td>------</td>
</tr>
</tbody>
</table>
• Multiply your total number of setbacks by 10.

<table>
<thead>
<tr>
<th>Number of setbacks</th>
<th>Total points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. **Material Choices**
Count up how many times you used each material in Table 8.1. Ignore choices that are not on the following materials list (e.g., start/stop mechanism). Complete Table 8.2 by multiplying the count of each particular material by its scaling term. Sum the total materials points.

Table 8.2

<table>
<thead>
<tr>
<th>Material</th>
<th>Count</th>
<th>Scaling term*</th>
<th>Total points</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLA</td>
<td></td>
<td>Multiply count x 40</td>
<td></td>
</tr>
<tr>
<td>PVC</td>
<td></td>
<td>Multiply count x 60</td>
<td></td>
</tr>
<tr>
<td>Silicone</td>
<td></td>
<td>Multiply count x 31</td>
<td></td>
</tr>
<tr>
<td>Wood</td>
<td></td>
<td>Multiply count x 17</td>
<td></td>
</tr>
<tr>
<td>Rubber</td>
<td></td>
<td>Multiply count x 27</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>-----</td>
<td>------------------</td>
<td>--------------</td>
</tr>
</tbody>
</table>

*See Justification of Materials Scores below for details.

**TOTAL**
Finally, add up all your points (from grayed areas) to determine your total score!

<table>
<thead>
<tr>
<th>Category</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cost</td>
<td></td>
</tr>
<tr>
<td>2. Setbacks</td>
<td></td>
</tr>
<tr>
<td>3. Materials</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
</tr>
</tbody>
</table>
Reflection

- Compare your score to your peers’ scores. Who scored lower? Can you determine why?
- In general, the more expensive solutions are also the more sustainable and environmentally friendly. However, an “ideal” sustainable solution may have exceeded your budget ($300), making the solution too expensive for its intended users. How do you balance tradeoffs to create a product that is both effective and financially feasible?

Justification of Materials Scores

These points are found using the Higg MSI, Materials Sustainability Index (https://msi.higg.org/page/msi-home). The lower the points, the lower the impact.

a. For PLA, you multiplied by 40:
   i. PLA has a 5.7 impact rating in terms of global warming
   ii. PLA has a 7.8 impact rating for eutrophication
   iii. PLA has a 7.2 impact rating for water scarcity
   iv. PLA has a 5.4 impact rating for resource depletion

b. For PVC, you multiplied by 60:
   PVC is not found on the index, but it is known to be very impactful for the environment and releases toxic chemicals that are damaging for human and plant health.

c. For Silicone, you multiplied by 31:
   i. Silicone Plastics have a 5.6 impact rating in terms of global warming
   ii. Silicone Plastics have a 2.9 impact rating for eutrophication
   iii. Silicone Plastics have a 2.7 impact rating for water scarcity
   iv. Silicone Plastics have a 6.2 impact rating for resource depletion

d. For Wood, you multiplied by 17:
   i. Wood has a 1.2 impact rating in terms of global warming
   ii. Wood has a 0.7 impact rating for eutrophication
   iii. Wood has a 0 impact rating for water scarcity
   iv. Wood has a 1.1 impact rating for resource depletion

e. For Rubber, you multiplied by 27:
   i. Rubber has a 4.0 impact rating in terms of global warming
   ii. Rubber has a 3.0 impact rating for eutrophication
   iii. Rubber has a 1.3 impact rating for water scarcity
   iv. Rubber has a 5.0 impact rating for resource depletion
In-Class Exercise LCA #4

Introduction
In this exercise, you will begin to think about the broader impact of your choices during the product design process. EGR 101 emphasizes the value of innovation, and you are given a full range of supplies to create something amazing. Yet, we often do not pause to reflect on the impact of each of those supplies. In this exercise, we compare the impact of six materials that are frequently used by EGR 101 students.

Task
Find five other classmates, for a total of six people. Each student should represent one of these assigned materials:
- PLA (polylactic acid, a type of plastic used in 3D printing)
- Wood
- Acrylic (type of plastic, often used in laser cutting)
- Steel hardware (e.g., screws, nuts, bolts, hooks)
- Polyester fabric (used in clothing and sheets)
- Polyethylene foam (used in packaging and insulation)

The goal of this activity is to line up from the least to the most impact on Global Warming. For example, does wood or fabric have a greater impact on Global Warming? After you are lined up for all six materials, check with an instructor or TA to find out what is correct.

Then, repeat this exercise for impact on Water Scarcity. A material that uses a lot of water would have high impact on Water Scarcity. After you are lined up for all six materials, check with an instructor or TA to find out what is correct.

As a group, answer these questions after learning the correct orders for Global Warming and Water Scarcity:
1. What assumptions did you initially make about the materials?
2. What surprised you?
3. How could you use something like the Higg Sustainability Index (https://msi.higg.org/page/MSI-home) to make design decisions?
4. Considering your product and the Higg Sustainability Index, would you choose different materials? Discuss why or why not.
Introduction
A life cycle analysis (LCA) is a method of assessing the social, economic, and environmental impacts associated with all the stages of the life cycle of a product. The assessment follows the product from the cradle, typically raw material extraction, to the product’s manufacture, distribution, and use, through the grave, or final disposal of the product and its materials.

In this activity, you will work with your team to identify what your product’s “grave” looks like. How will your product be disposed? Will any materials be recycled? What will go to landfill? What will be the environmental impact of your product’s disposal? Once you have identified the answers to these questions, spend some time writing a tribute - whether a poem, song, or rap - to your product, its impact on the world, and how it will spend the end of its life(cycle).

Task
- List out several key materials that your team used in your product.
- What impact will your materials have on the environment? You may find the Higg MSI Sustainability Index (https://msi.higg.org/page/msi-home) helpful in this.
- Do you expect that your product will be disposed of as a “whole” or disassembled to its component parts?
- Will your product be reused by a different person, or repurposed into a different function?
- Could you disassemble and recycle parts of the device? Is it realistic to expect that someone would disassemble your device?
- How are the materials in your device typically disposed of? What materials be could recycled and how?
- Will your product likely be thrown away in the trash, likely going to landfill?

Create a song, speech, poem, etc. about the end of your product. For example, you could write a song about how your product came to be (from humble materials), how it impacted the world by solving problems, and then how it spent thousands of years in a landfill.
The goal of today’s LCA carnival was to expose you to the environmental impacts of the design process and the relevance and importance of a Life Cycle Analysis. Now that you have engaged with each of the stations, discuss the following questions with your team.

1. Sustainability focuses on meeting the needs of the present without compromising the ability of future generations to meet their needs. Increasingly, designers and engineers must consider the resources needed to create and maintain new products through the lens of sustainability. How does sustainability connect to your project? Is it in tension with any of your design criteria? Why or why not?
2. If sustainability had been a design criterion, how would that have affected your research and brainstorming processes?
3. How would including sustainability have affected decisions in the Pugh matrices? How would this have changed your selected solution? How would it have affected your prototyping process?
4. Even if sustainability is not one of the design criteria, a design team can still make more ethically-driven decisions with regards to materials use, product longevity, etc. Can you think of other design criteria that would help your team consider the ethical impact of your design choices? How could you use these criteria to build a product with a lower environmental footprint and/or a longer life?
Appendix B

Student survey administered as pre- and post-survey.

<table>
<thead>
<tr>
<th>Questions – Part 1 (Duke developed Ethics &amp; Technology survey)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The most important consideration for an engineer or developer is that a product meets the design criteria.</td>
</tr>
<tr>
<td>2. If something goes wrong in a project, everyone involved is equally responsible.</td>
</tr>
<tr>
<td>3. The best technology is developed with minimal interference by government and regulators.</td>
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<tr>
<td>4. It is better to do good than to do bad.</td>
</tr>
<tr>
<td>5. When the government makes laws, the number one principle should be ensuring that everyone is treated fairly.</td>
</tr>
<tr>
<td>6. It is more important to be a team player than to express oneself.</td>
</tr>
<tr>
<td>7. It is permissible if some people are harmed as long as a product meets the design criteria.</td>
</tr>
<tr>
<td>8. Engineers should consider all possible use-cases and consequences before releasing a product.</td>
</tr>
<tr>
<td>9. There should be no upper limit on pay and benefits for someone with a rare skill set.</td>
</tr>
<tr>
<td>10. The best way to solve the problems facing the world today is through transparency and data-sharing.</td>
</tr>
<tr>
<td>11. People should be loyal to their family members, even when they have done something wrong.</td>
</tr>
<tr>
<td>12. Significant tradeoffs are necessary in the design of any product.</td>
</tr>
<tr>
<td>13. If someone is aware of an unethical practice at their company and does not speak out, they are also doing something unethical.</td>
</tr>
<tr>
<td>14. Too much regulation makes it hard for innovative ideas to get off the ground.</td>
</tr>
<tr>
<td>15. Everyone deserves to have the same opportunities in life.</td>
</tr>
<tr>
<td>16. Any algorithm that makes a choice important for society should be available for external review and critique.</td>
</tr>
<tr>
<td>17. There is a greater obligation to care for citizens of my own country than citizens of other countries.</td>
</tr>
<tr>
<td>18. People who do not like the features or effects of a piece of technology should simply not use it.</td>
</tr>
<tr>
<td>19. The designer has some moral responsibility if people use a product for some other purpose than its intended use-case.</td>
</tr>
<tr>
<td>20. People should be free to modify whatever technology they own.</td>
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<tr>
<td>21. The most important thing is that the same rules apply equally to everyone.</td>
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<tr>
<td>22. It is impossible to engineer a completely safe product.</td>
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<td>23. Anyone who works at a company has some responsibility for its practices, even if they have no decision-making authority.</td>
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<tr>
<td>24. People should be free to share copies of software.</td>
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<td>25. It is wrong for companies to lock in advantages that create barriers to entry for competitors.</td>
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<tr>
<td>26. It is a problem when users accept Terms of Service Agreements without truly reading and understanding how their data will be used.</td>
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<tr>
<td>27. Some tradeoffs with privacy are necessary in order to maximize transparency.</td>
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<tr>
<td>28. My country should use technological developments to gain an economic advantage in the global market.</td>
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<tr>
<td>29. Technology has the benefit of being neutral and objective.</td>
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<tr>
<td>30. It is never permissible to release a product that may not satisfy all safety criteria.</td>
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</table>
### Questions – Part 2 (MFQ)

<p>| | |</p>
<table>
<thead>
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<tbody>
<tr>
<td>31</td>
<td>Whether or not someone suffered emotionally</td>
</tr>
<tr>
<td>32</td>
<td>Whether or not some people were treated differently than others</td>
</tr>
<tr>
<td>33</td>
<td>Whether or not someone’s action showed love for his or her country</td>
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<tr>
<td>34</td>
<td>Whether or not someone showed a lack of respect for authority</td>
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<td>35</td>
<td>Whether or not someone violated standards of purity and decency</td>
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<td>36</td>
<td>Whether or not someone was good at math</td>
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<tr>
<td>37</td>
<td>Whether or not someone cared for someone weak or vulnerable</td>
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<td>38</td>
<td>Whether or not someone acted unfairly</td>
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<tr>
<td>39</td>
<td>Whether or not someone did something to betray his or her group</td>
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<tr>
<td>40</td>
<td>Whether or not someone conformed to the traditions of society</td>
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<tr>
<td>41</td>
<td>Whether or not someone did something disgusting</td>
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<tr>
<td>42</td>
<td>Whether or not someone was good at grammar</td>
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<tr>
<td>43</td>
<td>Whether or not someone was cruel</td>
</tr>
<tr>
<td>44</td>
<td>Whether or not someone was denied his or her rights</td>
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<tr>
<td>45</td>
<td>Whether or not someone showed a lack of loyalty</td>
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<tr>
<td>46</td>
<td>Whether or not an action caused chaos or disorder</td>
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<tr>
<td>47</td>
<td>Whether or not someone acted in a way that God would approve of</td>
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</table>

**Part 1:** Please read the following sentences and indicate your agreement or disagreement:

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<tbody>
<tr>
<td>Strongly disagree</td>
<td>Moderately disagree</td>
<td>Slightly disagree</td>
<td>Slightly agree</td>
<td>Moderately agree</td>
<td>Strongly agree</td>
</tr>
</tbody>
</table>

**Part 2:** When you decide whether something is right or wrong, to what extent are the following considerations relevant to your thinking? Please rate each statement using this scale:

[1] = not at all relevant (This consideration has nothing to do with my judgments of right and wrong)
[2] = not very relevant
[3] = slightly relevant
[4] = somewhat relevant
[5] = very relevant
[6] = extremely relevant (This is one of the most important factors when I judge right and wrong)
References


