The Final Straw: Incorporating accessibility and sustainability considerations into material selection decisions

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Abstract

Engineers are called upon to balance and adapt to the competing demands of industry, the environment, and society to develop sustainable and equitable solutions to modern problems. While traditional engineering programs provide students with the technical skills required of their profession, students often lack the knowledge and resources on how to incorporate complex environmental and social factors into decision-making so that they are prepared to face society's evolving challenges. As part of a larger initiative to integrate traditional technical skills with enhanced social awareness into the engineering curriculum, a two-part module emphasizing the environmental and social design considerations of sustainability was added to an existing module series in a third-year Materials Science course. This paper will describe the design, implementation, and assessment of one part of this module entitled "The Final Straw" that was focused on accessibility of straw materials within the disability community. For this module, groups of students considered the unique design needs of a marginalized stakeholder who relies on the material properties of single-used plastic straws (e.g., individuals with strength and mobility issues) to recommend an alternative material for the straw (e.g., paper, metal, silicone). In doing so, they must consider the larger economic, environmental, and social impacts of their material recommendation, and also consider how engineering design and public policy can unintentionally exclude vulnerable populations. Curricular content (e.g., homework, midterm questions) as well as researcher reflections were used to assess this module. Students were able to describe and synthesize the needs of multiple users with varying disabilities into a hierarchy of materials. While environmental considerations were not explicitly asked for, students could not detangle the environmental from the social aspects of this problem. However, framing the issue through the lens of accessibility could have allowed students to not consider the economic costs as primary and instead reframe them into a social consideration (i.e., cost to the consumer).

Introduction

Engineers are called upon to solve the world's most pressing problems, which are increasing in complexity and scope over time. Engineering programs within universities provide a solid technical foundation to solve these problems, often at the expense of contextual factors that are critical to addressing global issues such as sustainability, social impact and the environment. Helping students to address these contextual factors is critical to the development of an engineer graduate to have the skills and aptitudes needed for confronting the challenges of the 21st century. In recognition of this, considerations of social and environment context and factors are specifically stated in ABET student outcomes 2 and 4 [1].

Sustainability requires a balance between the competing interests of various stakeholders which form a Triple Bottom Line [2]. These three aspects, sometimes called the '3 Ps' are Economic (Profit), Environmental (Planet), and Social responsibility (People) [3] can be described as:

1. **Economic/Profit:** Businesses or countries must use resources efficiently and responsibly to produce an operational profit.

2. **Environmental/Planet:** Consumption of natural resources must be done at a rate that these resources can be replenished. Some resources are scarcer than others and damage to the environment must be considered.
3. **Social Responsibility/People:** Designs must be fair in distribution and opportunity by providing equitable opportunity and adequate social services including health, education, gender equity, and political participation.

While there has been work done to incorporate principles of sustainability into engineering classrooms [4]-[6], typically there is a focus on balancing economic and environmental aspects. Social aspects of sustainability are difficult to consider because they are difficult to quantify. While methods to quantify social impacts are being considered and tested [7], engineering students would benefit from the opportunity to engage with the social dimension of the Triple Bottom Line. An approachable way to do this is through the selection of materials. When selecting a material through the lens of sustainability, engineers must consider who benefits and who pays from that selection. This paper will describe how this was achieved by having students select a material for a straw by emphasizing accessibility for individuals with disabilities.

While the engineering education community is making strides to be more inclusive of people with disabilities, studies and classroom interventions often focus on design and capstone projects where engineering students designed for or interacted with members of the disability community [8], [9] or increasing accessibility to individuals with disabilities to broaden participation in engineering [10], [11]. In their review of the ASEE conference literature searching for papers related to disability, Svyantek found several categories including high and low design, perceptions and accommodations of students with disability within engineering, and access and inclusion [12]. However, when we searched the ASEE PEER database, we could not find any papers that framed accessibility as a social consideration when discussing the triple bottom line of sustainability.

This paper will focus on the development, delivery, and assessment of a newly developed module called “The Final Straw” module within a Materials Science course during Fall 2019. Using the example of single-use plastic straws and considering accessibility for the disabled community, this module helps students recognize the social aspects of materials selection. This work may be of interest to other engineering educators interested in finding creative ways to help their students achieve ABET students outcomes 2 and 4 which include social context and are sometimes difficult for engineering faculty to find ways to address.

Classroom Context

The module described in this paper was third in the series of four class periods incorporated throughout the semester that integrated social context into a technically focused course. This course, a third-year Engineering Materials Science course taught by the second author, is a required course for Integrated Engineering and an elective for Mechanical and Industrial and Systems Engineering students. This course was designed to introduce engineering students to the fundamentals of materials science engineering. Modules were accompanied by homework and exam questions to reinforce the relevance of these topics to the overall class. Incorporating social content into engineering courses requires an intentional, sustained, and consistent approach that bears in mind student’s limited time, conflicting priorities, and level of maturity.

Of the four modules, two have been utilized in previous iterations of the class and are described in [13] and [14], and two were newly developed for Fall 2019. These newly developed modules were a two part series named "The Final Straw" which covered the Triple Bottom Line of sustainability focusing on the social dimension using the example of plastic straws. "The Final Straw" was developed and delivered by the first author, a postdoctoral research associate with expertise in Environmental Engineering and Engineering Education, and guided by the second author, who is the instructor of record of the class with expertise in Materials Science, Electrical Engineering, and Engineering Education research. When creating "The Final Straw", active learning techniques such as peer-to-peer brainstorming and discussion were emphasized. For homework assignments, students worked in their cooperative learning homework teams where they did all homework for the semester.

This paper will focus on the second part of "The Final Straw", which is summarized in Table 1. A short summary of "The Final Straw" is provided below.

Table 1. Summary of "The Final Straw" part 2 within the MSE curriculum.

Module Title	**The Final Straw Part 2**
Date	Week 9: 11/1/2019
Description	Students discussed alternatives to plastic straws and used three case studies to explore how, for some users, plastic is a matter of accessibility and not convenience.
Associated homework and midterm content	HW#9 (Q4) MT#3 (Q7)

"The Final Straw" Module

This module focused on the issue of single-use plastic straws, a currently salient topic within media, policy initiatives such as the passage of plastic-straw bans in major cities like Seattle, and company initiatives to phase out plastic straws (e.g., Starbucks, American Airlines). The overarching goal of the Final Straw Module was:

> To enhance students' concept of engineering complexity to encompass non-technical (e.g., social, environmental, political) considerations, multiple stakeholders, multi-faceted problems, and the social and environmental implications of design decisions so that students are better prepared to make more socially conscious decisions in their professional careers.

This goal informed the inclusion of the major topics included in the "The Final Straw":

1. **Social Impact Analysis:** Incorporating social considerations into material selection decisions using the Social Impact Analysis Tool (Part 1).
2. **Accessibility:** Incorporating the voices of marginalized users into material selection by considering the needs of users in three separate case studies where using a plastic straw is a matter of accessibility rather than convenience (Part 2).

This module was split into two parts over two class periods. The first part of the module (i.e., Social Impact Analysis) was delivered during Week 7 of the semester and the second part (i.e.,

Accessibility) was delivered during Week 9. In the first part of the module, students were introduced to principles of sustainability, the environmental issues related to single use plastic, and introduced to an educational tool designed to help them assess the social impact of engineering design decisions. With this tool, they were required to make and justify decisions to change the material of a single use plastic straw and/or where the material originated, is manufactured, and disposed of.

Part two of "The Final Straw" builds upon this consideration of alternate materials for plastic straws and shows students that a solution that is environmentally friendly may result in unintended social consequences. Part two of the module included class and assessment activities which will be described in detail below.

"The Final Straw" Part 2: Accessibility

"The Final Straw" Part 2 was primarily designed to highlight possible tensions between the social and environmental aspects of sustainability using plastic straws as an example. Plastic straws are generally regarded as an environmental threat which was brought to the public's attention in a dramatic fashion in a viral video of a turtle having a straw pulled out of its nostril by a sea turtle biologist [15]. This has resulted in cities and states like Seattle and California instituting plastic straw bans [16], [17]. However, disability advocates have pushed back on blanket plastic straw bans, contending that plastic straws make it possible for them to consume beverages in public and that proposed alternatives are insufficient for their needs [18]. Through this module, students would become aware of and engage with the tension between environmentalism and accessibility through the lens of the disability community, whose voices are typically not included in design or policy decisions. By doing this, students will reflect on the role that engineers can play in mediating between the economic, social, and environmental factors that should be considered in making design and policy decisions.

The specific learning objective for this module are described in Table 2. Note that these are particularly related to ABET program outcomes 2, 3, and 4 which are

2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

3) an ability to communicate effectively with a range of audiences

4) 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 [1].

Table 2. Learning objectives of "The Final Straw" part 2, and associated curriculum used for assessment, and related ABET program outcomes

LO	Learning Objective	Assessed by	ABET program outcomes
LO1	Students will be able to describe and consider environmental, economic, and social considerations when selecting a material to use.	HW #9, Q4 MT#3, Q7	2, 3, 4
LO2	Students will be able to describe the strengths and limitations of alternative straw materials for specific users who relies on straws as a matter of accessibility instead of convenience.	MT#3, Q7	2, 3, 4
LO3	Students will be able to synthesize the needs of multiple users to create a hierarchy of alternative materials for straws.	HW #9, Q4	2, 3, 4

Students were introduced to several plastic straw alternatives and were provided examples of how companies were responding to plastic straw bans. For example, Aardvark straws are the only paper straw manufacturer in the United States and are expanding their operations because they cannot keep up with demand [19]. While paper straws were overwhelmingly seen in a negative light by the students for their tendency to get soggy and dissolve when using them, companies like Aardvark designed their paper straws to overcome some of these limitations. In groups, students were assigned a plastic straw alternative material and discussed the potential economic, environmental, and social impacts of using that material for straws. Following that, they were asked to determine if a straw made from that material had the characteristics shown in Table 3. Six plastic straw alternative materials were considered for this activity (i.e., paper, glass, stainless steel, silicone, bamboo, biodegradable plastic) based upon their widespread public usage.

The properties in Table 3 were modeled after an infographic created by disability advocates that illustrates why plastic straw alternatives do not work for many in their community for a variety of reasons [20]. After the activity, students were shown a video where members of the disability community spoke about why the properties of plastic straws were necessary for them to consume liquids [21]. In groups, students were given one of three case studies developed by the first author involving a scenario where an individual's respective needs required the use of a plastic straw. A description of these case studies is provided in Table 4.

Using the properties of Table 3, students were required to consider several alternative straw materials with their case study user in mind. Specifically, they were asked to identify which materials would definitely not work for that user and which could potentially work. The lesson ended by having students reflect on the underlying issue highlighted by this module, and what was at the core of this tension (i.e., not consulting the disability community).

Table 3. Table of plastic straw alternative materials and associated properties to consider.

Material	Single use	Allergy risk	Choking hazard	Injury risk	Flexible/ positionable	Temperature safe	Durability	Hard to sanitize	High cost
Paper									
Silicone									
Stainless Steel									
Glass									
Bamboo									
Biodegradeable Plastic									

Table 4. Description of the three case studies used in class.

Case Study	A: Cerebral Palsy	B: Autism Spectrum	C: Multiple Sclerosis
Scenario	Sam is a sophomore with a mild form of cerebral palsy studying Environmental Studies at his local university. He was invited by his friend, Maria, to a dinner on campus after a study session. He asks the employee for a plastic straw for his drink. Maria questions this decision because they learned about single-use plastic's effect on marine life in class. He forgot to bring his reusable straw. Maria questions if he really needs a plastic straw.	Darren is a five-year old child on the autism spectrum who likes the routine of going to the park every day. After a hot day, his mother, Eliza, knows Darren needs to rehydrate but the park snack-bar recently implemented a no plastic straw policy. Knowing that her son has particular sensory needs, she tries to find a substitute somewhere else.	Tara, a woman with multiple sclerosis, goes to a restaurant for dinner. She has tried using reusable straws before but developed an infection due to her weakened immune system. When the restaurant no longer automatically offers plastic straws, she has to explain her medical condition to the server.
Specific User Considerations	Difficulties drinking, chewing, and swallowing and risk of choking on liquid. Stiff limbs and involuntary spasms make it difficult to use utensils. Has a motorized scooter to aid mobility. Uncontrollable bite.	Highly sensitive to physical stimuli such as heat, cold, and textures. Reacts with anxiety and distress when overstimulated. Enjoys chewing on plastic straws. Comforted by routine.	Intermittent use of a wheel chair in public, low energy, weakened immune system, fatigued easily, medication must be taken at specific times, hand tremors, trouble tilting her head.

Related Homework and Midterm Content

Each student only engaged with one case study during the class period, but all were required to consider all three case studies for their homework assignment (HW #9 Question #4). The class activity was designed to have at least one student from each homework group engage with one of the case studies during the class period. For their homework assignment, they were required to consider the three users and their respective needs and create a hierarchy from best to worst straw alternatives to offer for the three individuals as if they were one group. They were then required to synthesize the rationale behind their hierarchy and describe a potential way to make the materials more accessible to all the users in the three case studies.

Some assessment of this module was also incorporated into the third midterm exam of the semester. The students were given the results of a survey of people with multiple types of disabilities conducted by disability advocates showing what percentage of the participants recommended a particular straw option or not [22]. Students were asked to recommend and justify a straw option based upon these results, explain why there might be such different opinions for an option, and then relate it back to two of the three case studies from class. A brief summary of the case studies was provided. Further information about the midterm question is provided in the Appendix.

Research participation and collected data

Twenty students were enrolled during the Fall 2019 semester from multiple engineering disciplines. These students were predominantly in their third year of study and majoring in Integrated Engineering. Students were required to participate in in-class activities, complete homework questions, and exam questions related to modular content. Students could opt to participate in the research through allowing the researcher to use their homework and midterm responses. Data was also generated through classroom observations and researcher reflection memos and used to inform the in class response results. Informed consent was obtained for these research activities. Table 5 describes the data sources that were collected and generated relevant to “The Final Straw” Part 2.

Table 5. Summary of data used for analysis.

Data Source	Description	Example question
HW#9, Q4	A homework question assigned directly after "The Final Straw" module was taught. Students had to create a hierarchy of six given alternative straw materials that would best suit the needs of the three users with disabilities described in the case studies provided in class. They had to justify their reasoning for their hierarchy and describe one way to make a straw material more accessible to the users in the case studies.	Combine and synthesize your experiences with three case studies to arrange the materials into a hierarchy from best to worst straw alternatives to offer for the three individuals as a group. Indicate whether this is an acceptable plastic straw alternative for the entire group, and provide a brief reason for your ranking in the table.
MT#3, Q7	A question integrated into the third exam administered during the semester. Students were given results from a report on straw material recommendation within the disability community [21] and asked to make a recommendation of material and provide an explanation for why one option had such a difference of opinion among the surveyed participants.	Why might there be different opinions for option D "stainless steel with silicone tips-bent"? Provide a general answer and then specifics including examples from at least two of the three case studies that we considered. (Note: some information provided on next page for case studies.)
Classroom observations	Researcher generated observations made during class. Observations informed the in-class response results.	N/A
Researcher Reflection Memos	Researcher generated reflective memos written after module curriculum was administered (i.e., classroom, homework, exam).	N/A

Results

1. Student Responses to "The Final Straw" Part 2: Accessibility

In-class response

Less than half of the students (8 out of 20) attended the second part of "The Final Straw" module. All students were still required to engage with the content of the case studies in their homework assignment and on a midterm exam question. Students considered alternative types of straw materials in a previous homework assignment, which acted as a starting point to consider these materials despite them not being explicitly covered in class. During their case study discussion, one student expressed confusion about how Case Study B (Autism spectrum) was related to design, and suggested that the case study involved a policy decision and not a design factor. The student was encouraged to think of the specific user described in the case study and what design considerations would be important to that user. Overall, there was a level of surprise

about considering the issue of plastic straws from this point of view. Only one student indicated that they were aware this issue of accessibility existed with plastic straws. This facilitated a discussion of current events salient to the area where a power company was shutting off power to homes in order to reduce the risk of starting a wildfire; the results of which affected the most medically vulnerable in the area [23].

Homework responses

All student homework groups were able to create a hierarchy of plastic straw alternatives and indicated whether some materials would be unacceptable for the users in the case studies. The hierarchy varied between student groups, but biodegradable plastic and silicone straws were overwhelmingly seen as acceptable alternatives, while stainless steel, glass, and bamboo were unacceptable due to their injury risk for the users in the case study. Opinions of paper straws were mixed, with some students stating that they presented a choking hazard and others not mentioning this hazard and focusing on their biodegradable qualities as a plus to the environment.

While all groups had a unique ranked hierarchy of materials, at least 3 out of 5 groups agreed on the placement of materials on the hierarchy, and students completely agreed on whether a material was an acceptable alternative on 4 out of the 6 materials. Students had varying opinions about whether paper was an acceptable alternative. While 'maybe' was not presented as an option in the assignment, two groups used it for paper, two groups said no, and one group said paper was acceptable. This overall ranking of materials and perceived acceptability to the users in the case studies is provided in Table 6.

Table 6. Compiled ranking of acceptable straw material for individuals in the three case studies.

Material	**Ranking**		**Acceptable Alternative?**	
	Rank	**# of groups ranked (out of 5)**	**Yes/Maybe/No**	**# of groups with this response (out of 5)**
Biodegradeable Plastic	1st (Best)	4	Yes	5
Silicone	2nd	4	Yes	5
Paper	3rd	3	Maybe*	2
Bamboo	4th	3	No	3
Stainless Steel	5th	3	No	5
Glass	6th (Worst)	3	No	5
* One group said acceptable, two said unacceptable and two said maybe acceptable. Students were only prompted to use yes or no.				

All student groups were able to describe the injury risks that more rigid straws posed for Case Study A, the importance of texture or overstimulation for Case Study B, and the health risks for Case Study C. On the other hand, few student groups took into account the necessity of positioning a straw and having it keep that position for Case Study A and C. Other responses included considering the cost to the consumer, temperature, and factors related to the environment. One group in particular had a strategic approach to arranging their hierarchy using

environmental factors. Their initial approach considered only safety and injury risk to the users and used environmental factors to rank the unacceptable materials. They stated,

> *We valued that the safety of the user was the most important factor, that's why stainless steel and glass were discarded, our user could get hurt by choking or chewing on the straw. Then the bamboo was also discarded because it does not provide the accessibility because it is not flexible. Then we chose the silicone as the best material because it can be reused, only in the case if the user is not allergic to silicone and if he is able to sanitize the straw. Biodegradeable plastic and paper are also viable solutions, but they are single use materials.* (Source: HW#9, Q4)

Midterm Responses

For the first part of the midterm question, students were required use data provided from a survey of the disability community to indicate which straw out of seven options they would recommend for use. Most students (17 out of 20) selected the correct straw option based upon its high recommendation by the disability community. The second part of the question asked students to consider why there might be differences of opinion on a particular option (i.e., a bent stainless steel straw with silicone tip) and relate it to the three users in the case studies they engaged with in class and on their homework. Through this question, students were able to compare and contrast the various users within the case studies and their often differing needs. In particular, students mentioned the user in Case Study B (Autism spectrum) being overstimulated by textures and temperature. Students also brought up issues of safety and risk of injury, physical properties of the straw especially if they were linked to motor control issues. The most ambiguous case study to students was the Case Study A (Cerebral Palsy). It was intentionally created to reflect a mild condition to show the range of the spectrum within the disability community and within a disability itself.

There was a limited understand of the usefulness and efficacy of the silicone tip in being able to address the needs of the users in the case studies. Students specified there is a safety issue with biting rigid straws (e.g., metal) but some made the assumption that a user would only bite on the silicone tip. Another area of limited understanding was about a structural bend in a straw and equating that to being positionable, and that this bend in the straw would be enough to compensate for the user who had trouble tilting their head. The frequency of student mentions of important factors on MT#3 Q7 is provided in Table 7.

While the midterm questions specifically elicited social considerations, many students integrated environmental considerations into their responses. This was especially true for the first part of the question where 11 out of 20 students mentioned environmental factors. This was usually in the form of an addendum to the correct answer that users recommended the option. For example, one student responded to what they would recommend by saying, "Compostable plastic straw. It had most recommended and least not recommended. Also it's compostable, so plastic won't go in ocean" (Source: MT#3, Q7). While this student is making an assumption that this type of straw is compostable in non-industrial conditions, its inclusion shows that environmental considerations are important to them. In some cases, those environmental considerations superseded the social considerations. For example, one student stated,

I would recommend the stainless steel straw with silicone tips because it is recommended more than paper straws and more environmentally friendly than plastic straws. Although some people do not recommend, the design can be improved upon. Plastic is too harmful to the environment. (Source: MT#3, Q7)

Table 7. The most frequently listed factors for MT#3 Q7 responses

Factor	Examples	Number of mentions	Case Study Most Associated with
Stimuli	Texture, temperature, comfort, familiarity	16	B (Autism spectrum)
Safety	Breaking teeth from uncontrollable bite, choking	15	A (Cerebral Palsy)
Physical properties	Bend in straw, able to position straw	14	C (Multiple Sclerosis)
Motor control	Tilting head, dexterity, tremors, jaw control, low mobility	14	A and C
Environmental considerations	Compostable, recyclable	14	N/A
Health and sanitation	Cleaning straw, weakened immune system	10	C
Convenience	Single use, available everywhere	4	N/A

Discussion

In light of these results, the student achievement of the specific learning outcomes of the module is discussed below.

LO1: Students will be able to describe and consider environmental, economic, and social considerations when selecting a material to use.

Students were able to describe social considerations within the assignment and midterm responses when considering an alternative material for the three users with varying needs in the case studies. Specifically, students were able to describe social considerations related to being overstimulated (e.g., texture), the safety of the user (e.g., injury from uncontrollable bite), and the user's limited motor control (e.g., tremors). These social considerations were explicitly asked for. Without being prompted, students also brought up environmental factors related to the straw material choice almost as much as social factors. Drawing on previous class discussions, many of these students are attuned to the environmental issues related to single-use plastic. Five students in the class have a specific concentration in sustainability, which could have also contributed to their interest in environmental considerations.

Students expressed less consideration of the economic factors of design when the issue was framed through the lens of accessibility. When cost was mentioned in student responses to their homework assignment or exam, this cost was considered from the point of view of the consumer rather than the cost to produce and manufacture the material. This could be because a more

human face was put on the issue through the inclusion of case studies and watching a YouTube video where members of the disability community discussed their issues.

LO2: Students will be able to describe the strengths and limitations of alternative straw materials for specific users who relies on straws as a matter of accessibility instead of convenience.

The students were able to discuss the strengths and limitations of straw materials to an extent. They displayed a high consideration of issues related to being over stimulated and safety. In particular, they described issues related to uncontrollable biting and why more rigid straws would not work for Case Study A (Cerebral Palsy), the reactions to being overstimulated for Case Study B (Autism spectrum),and the health related needs for Case Study C (MS). However, students showed an incomplete understanding of the necessity for a bend in the straw and especially the ability to position a straw. Some student responses equated a bend in a rigid straw to be an acceptable substitute for a user who had trouble tilting their head. Additionally, the mixed response to a paper straw being an acceptable alternative for the users in the three case studies did not consider the possibility of choking, biting through the straw, and the ability to position the straw.

LO3: Students will be able to synthesize the needs of multiple users to create a hierarchy of alternative materials for straws.

Students were able to synthesize the needs of multiple users in the three case studies and created unique hierarchies of materials. All groups considered biodegreadable plastic and silicone as acceptable alternatives and the best out of those presented. Biodegradeable plastic had the most similar properties to the plastic straws the users relied on, and silicone had enough similar properties that it was deemed acceptable. All groups also considered stainless steel and glass unacceptable alternatives and ranked them the lowest. This was mostly due to the safety risk they carried due to their rigidity in light of the user who could not control their bite. Bamboo had a slight difference of opinion, but was mostly seen as unacceptable due to the safety risk of its rigidity. Students were less sure about the accessibility of paper straws. Several groups did not consider the safety risk (i.e., choking) that the straws could pose and instead focused on the environmental benefit of using paper straws.

ABET outcomes

Students were able to apply their engineering knowledge to select acceptable materials for a straw for users with specific needs (Outcome #2) as evidenced by the hierarchy of alternative materials. An important aspect of communication is the ability to listen. Through the midterm question, students recognized the importance of listening to the recommendations of the disability community in selecting a straw material (Outcome #3). Finally, through engaging with this module, students were able to make better informed judgments which consider the impact of material section on the disability community through the example of plastic straws (Outcome #4).

Conclusions

In "The Final Straw" module, students engaged specifically with a social aspect of the Triple Bottom Line on the salient environmental issue of single-use plastic straws through the selection of alternative materials. Students were able to describe and synthesize the needs of multiple users with varying disabilities into a hierarchy of materials. While environmental considerations were not explicitly asked for, students could not detangle the environmental from the social aspects of this problem. However, framing the issue through the lens of accessibility could have allowed students to not consider the economic costs as primary and instead reframe them into a social consideration (i.e., cost to the consumer).

Limitations

The results of this paper describe one class period set in the middle of a larger effort to incorporate more social and environmental content into a materials science course. Student responses to the other integrated modules as a whole were collected, but not considered for this paper. Because this module was developed while the class was being taught, certain logistical issues could be avoided on subsequent iterations. For example, the placement of this module in the course schedule could be more strategic. The low in-class attendance could be a result of students attending conferences, the class occurring directly after an exam, and students being aware that their instructor's planned absence. Lastly, integration of feedback about the accessibility case studies was elicited from professionals with expertise with the disability community but not enough time was given to incorporate that feedback before the class was taught. Future iterations of this module will have updated case studies incorporating this feedback.

Future Directions

This module could possibly be used to engender empathy for individuals with disabilities within engineering students. Schmitt and colleagues described how they have used design projects to achieve this focusing on user-inclusive design [24]. Learning outcomes specific to developing empathy could be integrated into future iterations of this module or similar modules. The smaller scale may make it more accessible for engineering educators to utilize within second and third year classes which are often purely technical and where students struggle to find relevance [25]. The case studies and the YouTube video helped put a human face on the issues the disability community faced concerning plastic straws. Taking this a step forward could potentially include bringing a disability advocate into the classroom to speak about their personal experiences.

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Appendix

Curricular content (*MT#3, Q7)*

[11 pts] (7) After plastic straw bans were proposed in California in 2018, disability advocates conducted a survey of people with multiple types of disabilities. Participants were asked to try several types of straws and report whether they recommended using them or not. Figure MT7-1 shows the results of the survey.

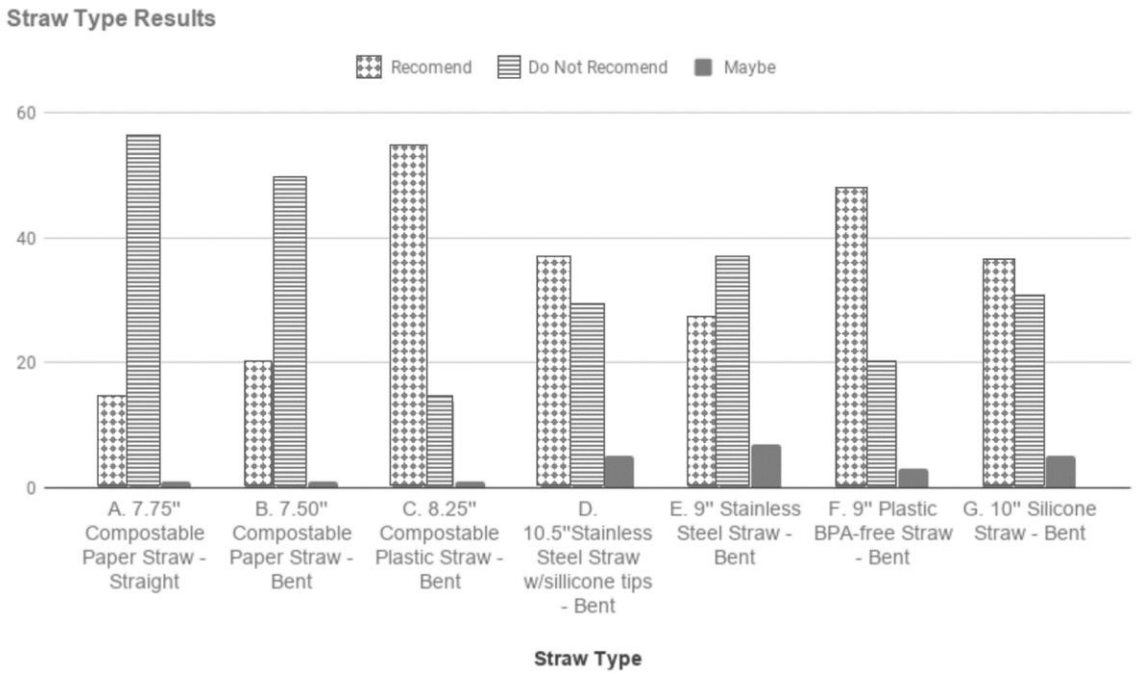

Figure 1. Straw type recommendation survey results of disability community (adapted from [22])

Demographics of Survey Respondents:

- 25% identified as having sensory-related disabilities (e.g. autism, visual, or hearing impairments)
- 56% identified as having their disabilities impact their dexterity (e.g. cerebral palsy or multiple sclerosis)
- 44% currently rely on a plastic straw (Option F in Figure MT7-1).

1. Given these results, which straw would you recommend for use? Why?

2. Why might there be different opinions for option D “stainless steel with silicone tips-bent”? Provide a general answer and then specifics including examples from at least two of the three case studies that we considered in ENGR 311. (Note: some information provided on next page for case studies.)