Investigating using a “Social Impact Audit” Tool to support students’ decision-making in a Materials Science Course

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***Abstract*— This innovative practice full paper describes the design, implementation, lessons learned, and student feedback from the creation of a new module “The Final Straw” in a required Engineering Materials Science class for third-year engineering students. This module used the example of single-use plastic straws and material alternatives to make informed decisions that consider the impact of engineering solutions in global, economic, environmental, and societal contexts. Students were introduced to the Social Impact Audit (SIA) tool, a macro-enabled Excel workbook, developed by Ansys/Granta, that uses data from the United Nations Environment Programme and Society of Environmental Toxicology and Chemistry to evaluate and compare the social impact of a product’s lifecycle. Based upon the social impacts revealed through SIA, students were required to make and justify recommendations on changing the material a straw was made from and/or the nations where the material originated, was manufactured, or disposed in. Student learning was assessed using homework and exam problems. Student feedback was obtained through voluntary surveys. Preliminary results indicate that students found the SIA tool easy to use, but would have liked a more sophisticated analysis of the intersection of social and economic considerations. Additionally, despite being required to focus on social impacts, students often attributed more importance to economic and environmental considerations when making material selection decisions.**

Keywords—social impact, materials science, sustainability, undergraduates

I. Introduction

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. ABET has also recognized this need to incorporate considerations of social and environment context specifically through student outcomes 2 and 4 [1], 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

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.

Consideration of social context is particularly challenging as methods for assessing social costs of the lifecycle of products are still being developed [2], [3]. Previous work has explored skills engineering students need to assess the global and societal impact of their solutions [4], how to incorporate more social science and liberal arts content within engineering [5], [6], and integrating social, environmental, and humanitarian context throughout specific engineering classes [7] – [9]. This is also important within materials science, where calls for changes to existing curricula have been made to provide meaningful context and include other design constraints such as environmental, societal, sustainability, ethical, and political [10].

This paper focuses on the development, delivery, and assessment of a module called “The Final Straw” within a Materials Science course during Fall 2019 which used the Social Impact Audit (SIA) tool currently in development by researchers at ANSYS/Granta [2]. We designed this module around the material selection of single use plastic (SUP) straws and alternatives (e.g., glass, stainless steel) using the SIA tool. The purpose of the tool is to estimate the impact of a product’s life cycle on the well-being of the people within the countries involved so that students could compare the impact of material alternatives. With this tool, students were required to consider the impact of their decisions in a global, economic, environmental, and societal context. This work may be of interest to other engineering educators interested in finding

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creative ways to help their students achieve ABET student outcomes 2 and 4, which include social context [1].

II. Module Design

The module described in this paper was second in a series of four non-consecutive class periods incorporated throughout the Fall 2019 semester that integrated social context into a Materials Science course. This paper focuses on the first part of "The Final Straw", which included in-class activities and homework and exam questions to reinforce the relevance of these topics to the overall course and so that students could engage with the content in a deeper way. When creating this module, active learning techniques such as peer-to-peer brainstorming and discussion were emphasized. To facilitate this active learning component outside of classroom time, students were required to complete their assignments in cooperative learning homework teams.

A. The Final Straw

This module was framed around the issue of SUP straws, a salient topic owing to media attention and policy and industry initiatives such as the passage of plastic-straw bans in major cities and company plans to phase out plastic straws (e.g., Starbucks [11], American Airlines [12]). 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.

The specific learning objectives for this module are described in Table I. Note that these are particularly related to ABET program outcomes 2 and 4 [1].

TABLE I. LEARNING OBJECTIVES OF THE FINAL STRAW, ASSOCIATED CURRICULUM USED FOR ASSESSMENT, AND RELATED ABET PROGRAM OUTCOME

LO	Learning Objective	Assessed by	ABET outcomes
LO1	Students will be able to describe and consider environmental, economic, and social considerations when selecting a material to use	Homework #6, Question 6 & Homework #8	2, 4
LO2	Students will be able to make and justify a recommendation for change of material and/or change of material origin, production, or end of life based upon the Social Impact Audit tool	Homework #8, Midterm #2 Question 7	2, 4

B. Description of Module

In class, students discussed the material properties of SUP that make it ideal for straws but have resulted in their ubiquitous and environmentally deleterious use. Students were then introduced to a brief overview of sustainable design and the triple bottom line of people (social), planet (environmental), and profit (economic) [13]. We intentionally highlighted that the social component of sustainable design is the least emphasized within engineering design within the classroom. For example, methods have been developed and refined to measure economic and environmental impact (e.g., Design and Life Cycle Costing [14] and Environmental Life Cycle Analysis [15]), but engineers are still struggling to implement methods to assess social-life cycle analysis [2]. One method in development is Social-Life Cycle Analysis (S-LCA), which assesses social and socio-economic impacts found along a product's life cycle (e.g., extraction and processing of materials; manufacturing, distribution; use; maintenance; recycling; and final disposal) to promote improvement of social conditions throughout the lifecycle of a product [3]. While this method is still in development, ANSYS/Granta developed an educational tool called the Social Impact Audit (SIA), which is intended to provide an introduction to more advanced S-LCA methods in a format that is easy for students to use. With permission from ANSYS/Granta, we were provided access to and allowed to use this tool with our students.

C. Description of the Social Impact Audit tool

The SIA tool is a macro-enabled Excel workbook which focuses on the behavior of those making a product and the social and political norms of the nations that these products are produced, manufactured, used, and disposed in [2]. It uses data from United Nations Environment Programme (UNEP) and Society of Environmental Toxicology and Chemistry (SETAC) guidelines and impact indicators assembled by governments and non-governmental organizations. The purpose of the tool is to estimate the impact of the product life cycle on the well-being of the stakeholders within those countries with the goal of improving social conditions and identifying 'social hot-spots'. A social hot-spot is a "point of contact between stakeholders and aspects of the materials, manufacture, distribution and use of the product that may, potentially, be damaging or could be influenced in a positive way" [2, p. 4]. The SIA tool incorporates impact categories (i.e., measurable ways stakeholders are affected such as child labor) to help the user make decisions. The SIA tool provides additional information on impact categories including a description, how indicators are calculated, and relevant weblinks to data sources. This allows the user to further research an impact category and how it could potentially affect stakeholders or stage of a material's life cycle. This data was scaled within the SIA tool on a scale of 1 to 100, where 1 would be the worst practice and 100 the best, in order to make comparisons between different nations. While all of these indicators have different units of measurement, because they are scaled in the tool, the user is able to compare practices in nations with each other directly.

D. How to use the SIA tool

Users must select a material and identify nations used for the material's sourcing, manufacture, and end of life. When introducing the SIA tool to students, the example of polypropylene for SUP straws was chosen based upon easily accessible information about where polypropylene originates, is manufactured, and potential end of life routes. To further simplify the example for students, considerations of transport of the material was omitted. Further assumptions were made for the sake of the exercise, including that polypropylene—which is technically recyclable but the size and shape of straws makes it practically infeasible—would be sent to another country for recycling. Nations were selected for this case study to provide the students with several potential social hot-spots to consider in the context of current events.

Nations were selected in the SIA tool and a hot-spot threshold, between 0 and 100, chosen by the user. This hot-spot threshold is used to determine which areas are cause for concern. If the numerical values of the indicators for a given stakeholder group fall below this threshold, it is a cause of concern for the wellbeing of that stakeholder group. The tool generates a report of the selected nations where any indicators below the threshold are shown as red Xs where the Xs indicate the indicators being farther below the threshold and thus more cause for concern. The user then has to fill out a Hot-Spot Summary table using the report. For example, the case example provided to students is shown in Figure 1. From this table shown in Figure 1, students can see that for the origin of the material the areas of most concern would be S3 Local Community and Manufacture and S5 Value Chain for origin as they have the most Xs.

Life phase	NATION	S1 Workers	S2 Consumers	S3 Local community	S4 Society	S5 Value chain (others)
Origin	VEN	X	X	XX	X	XXX
Manufacture	CHN		XX	XXX		
Used in	USA				X	
End of Life	INA		X	X	X	X

Fig. 1. Hot-spot summary for SUP straws made from polypropylene using default hot-spot threshold of 20.

These hot-spots point the user towards areas of further research and consideration. The summary table, while not providing much information in itself, serves as a tool of further investigation for the user. The user is then invited to report any significant concerns or opportunities based upon the results of their audit, and to make recommendations. Potential recommendations could include changing a material, changing a process in the life phase, or changing a nation the process is conducted in.

E. Related Homework and Midterm Content

To prepare students for the module, students were assigned a homework problem (Homework (HW) #6, Question 6) prior to the planned lesson date. This homework assignment was used to begin discussion during class as students were asked to reflect on the role that engineers play in making decisions that incorporate social context. After the class, students were assigned a weekly homework set (HW #8) relating to the SIA tool to ensure students engaged with the content of the module and had experience using the SIA tool. Following this, students were required to answer a question related to SIA on their second exam of the semester. A description of these curriculum activities is provided in Table II.

III. 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 and Mechanical 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 curriculum content responses and filling out surveys. Informed consent was obtained for these research activities. Table II describes the data sources that were collected and generated for this module.

TABLE II. Summary of curriculum and data collected.

Data Source	Description
HW#6, Q6	A homework problem incorporated into an assignment to prepare students for the material covered in the Final Straw. This question provided students with some background information on the Great Pacific Garbage Patch a relevant and local environmental issue to San Diego [16] and the associated issue of microplastics [17]. This content was further contextualized using an example of a solar powered robotic skimming device that engineering students from their university assisted in building and testing [18]. This homework assignment was used to begin discussion during class as students were asked to reflect on the role that engineers play in making decisions that incorporate social context.
HW#8	An entire homework assignment using the SIA tool. Students were required to consider alternate choices for a straw to the proposed case example of SUP. They were prompted to change either the material of the straw (e.g., paper, stainless steel) and/or the source of the material with an accompanying cited reason to support their decision. Following this, they produced a hot spot table (such as the one shown in Figure 1), identified significant concerns and opportunities, justified their final decisions, and described at least three potential economic, environmental, political, or other repercussions of their final design decisions.
MT#2, Question 7	A question integrated into the second exam administered during the semester. Students were given a scenario where their employer wanted them to perform a quick social audit to suggest an area of investigation within their current production life cycle. The students were provided with a pre-generated hot-spot table with hypothetical nations labeled A, B, C, and D, a threshold limit of 20, and a table of impact indicators for stakeholder categories with normalized scores to compare between nations (e.g., S1: Hours worked per week: 9.0).
Feedback survey on SIA tool	Feedback was elicited from students in class about their experiences using the SIA tool including how they used the tool in their homework assignment and how it helped or hindered making a decision about the sourcing and type of material.
The Final Straw Post-class survey	An online survey created on Google Forms with both quantitative and qualitative items to evaluate attitudes towards "The Final Straw" module to both improve future offerings and to evaluate the learning outcomes.

IV. Results

A. Student Response to the Module and the SIA tool

A voluntary online survey was sent to all students after the completion of the module. Only 7 out of 20 students opted to participate, and their responses are described below. While no statistical significance can be derived from these results, they can be used to improve future course offerings. Overall, these students found the SIA tool easy to use and rated it an average score of 4.4 on a scale of 5, where 1 = Difficult to Use and 5 = Easy to Use. When considering the information the tool provided, students thought the information was valuable with an average score of 4.0 out of 5.0. When considering if the SIA tool helped them consider social issues into engineering design decisions, the students saw it as helpful with an average score of 3.7 out of 5.0. Students also reported that the topics within the module mattered to them as an engineer (4.7 out of 5.0). These are summarized in Table III.

TABLE III. SUMMARY OF STUDENT SURVEY RESPONSES.

On a scale of 1-5 rate how much you agree with the following statement	Average Student Response (out of 5)
I think that the topics we covered in The Final Straw module matter to me as an engineer.	4.7
The SIA tool was easy to use.	4.4
The SIA tool provided information that was valuable.	4.0
Using the SIA tool in my homework helped me consider and weigh social issues in making engineering decisions.	3.7

B. *Student Issues in Using SIA*

The midterm question (MT#2, Q7) was designed to assess if students understood how to use the SIA tool. Thus, the exam question was structured to use the tool more in a quick audit capacity to recommend further research into a practice and associated nation rather than identifying specific concerns and opportunities as they did on HW#8. The majority of the students (16 out of 20) were able to identify an appropriate nation and corresponding life phase that merited further investigation and reasonably justify their response. The average score was 8.5 out of 10 points for this midterm question.

From the midterm responses, several misconceptions and misunderstandings about the numbers in the SIA tool were apparent. For example, one student indicated that the score was a probability rather than a scaled number to measure against other nations. They stated:

> *I would say that manufacturing in nation B requires an investigation due to the S1 workers category. It is alarming to me that* ***it has a score of 14.0 fatal accidents at work****. This is an extreme amount of deaths in a workplace and it pushes me to ask what regulations and precautions were taken to ensure the safety of these employees. Even if one person's life is taken it's a problem, but the score implies that multiple lives have been taken, this is deeply concerning, especially considering its score.* ***If 14/20 correlates to the probability of a fatal accident then that means there is a 70% chance of it occurring,*** *this is really bad.* (Source: MT#2, Q7, emphasis bolded by the researcher)

On the midterm, some students attributed units to these scores which affected their interpretation of the presented information. For example, one student wrote:

> *Nation B and the manufacturing stage need further investigation. The S1: workers and S4: society do not meet the desired threshold of 20. Fatal accidents at work and only* ***9 hour work weeks*** *are a problem because it's dangerous to workers and they're not working as much.* (Source: MT#2, Q7, emphasis bolded by the researcher)

In this particular example, 9 is not the number of hours of work per week but it is the scaled rating of Nation B for this category out of 100. Thus, 9 is a low value and merits further consideration.

Additionally, students expressed confusion over the threshold limit and what exactly it meant for the impact categories. The numbers reported in the SIA tool are scaled against each other based upon nation's practice relative to another. While students found the numbers made it easy to compare nations, their actual social meaning and cost was muddled and required additional research. Surprisingly, in Homework 8, students set their threshold limit much higher than the default of 20 in their assignments. Groups threshold limits ranged from 25 to 50. This meant that they were considering these decisions from a more socially stringent point of view than suggested by the SIA tool.

C. *Economic and Environmental Aspects of Sustainability Take Precedence Over Social*

Student homework and in-class discussion responses for HW#6 (Q6) indicated that most students understood the technical aspects of why the example of an engineering intervention was inadequate to address the issue of the Great Pacific Garbage Patch (e.g., microplastics are too small to pick up with a robotic skimmer, depth of the plastic in the ocean, time and range limitations of skimmer device being remotely controlled), with some students describing environmental issues (e.g., harming marine life). When specifically prompted for non-technical solutions, students brought up social aspects. Of these solutions, policy solutions were the most frequently mentioned solution (3 out of 5 homework groups), with two groups mentioning policies that tax companies for bad behavior, and one group mentioning policies that reward companies for good behavior. Despite asking for non-technical solutions, two out of five groups provided technical solutions.

Student focus on environmental and economic over the social aspects was also present in HW#8. When students were asked to make a change (i.e., nation, straw material), all homework groups changed the straw material to either a more biodegradeable or reusable option. The types of alternate straw materials students considered with the SIA tool is provided in Table IV . Students assessed up to two alternative materials to plastic straws, and their initial stated reason for selecting a material was specifically an environmental reason. As students proceeded throughout the assignment, many groups reframed social impacts specifically through their economic and environmental costs.

TABLE IV. STUDENTS SELECTED ALTERNATIVE STRAW MATERIALS BASED UPON ENVIRONMENTAL CONSIDERATIONS.

Proposed Alternative Straw Material	**Stated reason why selected**
Bamboo	"Bamboo is biodegradeable."
Stainless Steel	"Durable, stain resistant, recyclable."
Wheat	"Wheat is naturally biodegradable and production leaves byproduct for straws."
Pasta/Rice	"Compared to plastic straws, rice flour straws are fully compostable while retaining their structural integrity."
Glass	"Glass is 100% recyclable."

Economic considerations pervaded students' analysis and responses. For example, when asked to justify their design decision where one group selected China as a nation to manufacture bamboo straws, they acknowledged the negative social impact and stated, "[…] we wanted to make sure our business could make a profit so we had to go with the cheapest manufacturing route even though China does not have a good social impact analysis" (Source: HW #8, Q4 Design Justifications). Student perception of environmental and economic importance was also apparent on the midterm question. While only social considerations were specifically elicited for the midterm prompt, 5 students included environmental considerations and 2 students included economic considerations in their responses.

Despite this, some student groups showed a deeper understanding of the interplay between economic, social, and environmental considerations from using the tool. For example, one group selected a straw made from rice flour because of its environmental benefit (i.e., it is compostable) and stated:

> *From the SIA-tool and hot spot summary, the biggest concerns would be the socio-economic violations countries such as Vietnam and Indonesia have compared to other nations such as the U.S. Both Indonesia and Vietnam have limited worker and consumer protections and fail to protect their communities and constituents. This calls to issues of capitalism and exploitation of third world countries, where our purchasing power can perpetuate the poverty that working in these so called "sweatshops" endure. However, producing the straws in these countries presents an economic opportunity, as manufacturing and shipping costs are lower than in the U.S. […]* (Source= HW#8, Q3 Concerns and Opportunities)

D. Quantitative approach to social impact

From analyzing their curricula data and when soliciting feedback from students, students indicated a preference for using comparable numbers (i.e., cost in dollars) to measure the social, economic, and environmental dimensions of sustainability. For example, students mentioned they found the tool easy to use and liked the information about worker's rights, but they wished the tool related more closely to economic indicators. They wanted to see how the social indicators related to the economic. For example, one student stated, "I just hoped there could be an economic parameter because usually the countries that have a better impact are more expensive" (Source: Feedback survey on SIA tool). Another student saw the importance of the intersection of the economic and social dimensions, but for a different reason, hoping for a more nuanced approach to social impact that considered economics. They stated, "I wish that the SIA excel tool accounted for how producing a material in a country can economically benefit the country by providing work for its citizens" (Source: Feedback survey on SIA tool).

V. DISCUSSION

Student achievement of the specific learning outcomes of the module is discussed below.

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

In HW#6, Q6 and HW#8, students identified and examined the environmental, economic, and social considerations relating to SUP, specifically the Great Pacific Garbage patch and plastic straws. Students easily recognized the negative environmental impacts of SUP on marine life and were able to describe the environmental benefits of reusable (e.g., stainless steel) and biodegradable (e.g., rice-flour) straws. All student groups opted to change the material of the straw for HW#8 for environmental reasons, and gave weight to economic considerations in justifying their decisions on where the material originated from, was produced, and disposed of. The SIA tool provided students with a starting point to consider and compare the social impact of their decisions based upon the nations they selected.

B. LO2: Students will be able to make and justify a recommendation for change of material and/or change of material origin, production, or end of life based upon the Social Impact Audit tool

Students were able to use the SIA tool to make and justify a recommendation for change of material and change of material origin, production, and end of life in HW#8. The majority of students were able to synthesize information taken from the SIA tool for MT#2, Q7 and justify their recommendation to investigate a life-cycle phase and corresponding nation using social considerations.

C. ABET outcomes

Students were able to apply their engineering knowledge to select acceptable materials for a straw considering economic, environmental and social factors (Outcome #2) as evidenced by their responses to HW#8 and their midterm question. Additionally, by using the SIA tool, students considered their material selection decisions in a global context by comparing the social impact of their material's origin, production location, and end of life destination. Even with an explicit focus on social impact, students naturally incorporated environmental and economic contexts into their design justifications and potential repercussions (Outcome #4). Through this module, students grappled with balancing their professional responsibility as an engineer towards their employer and to society.

D. Limitations

It is important to provide engineering students with ways to approach the social impacts of their engineering decisions. Economic and environmental design considerations already have established quantitative methods of analysis, but social considerations are not as easily quantified. The way the SIA tool was set up provided a way to compare the social impact among multiple nations on dozens of indicators such as minimum wage and political stability and encouraged students to dig deeper on material selection decisions on a non-superficial level. However, the way the SIA tool is set up could potentially put the blame on nations themselves, rather than specific companies/business operating within those nations. Students could make the decision to choose a more socially conscious nation based upon the indicators from the SIA tool, but that would not bring about change nor benefit the people who are living and working in nations which score poorly on the SIA and need the most support.

VI. Conclusions

Students found the SIA tool easy to use and found the information within it valuable. However, students were less sure that the SIA tool helped them weigh social issues when making engineering decisions such as material selection throughout a product's lifecycle. From the responses to their homework assignments, it was clear that students more easily understood environmental and economic aspects over social aspects of material selection decisions. This was further exemplified by classroom discussion where students expressed their opinion that economic and environmental factors were more palatable to companies in making material selection decisions. Additionally, while the SIA tool helps quantify social impact in a way more accessible to engineering students, they would have liked the SIA tool to include a more sophisticated analysis of the intersection of social and economic considerations that was also quantitative. While there was a tendency of some students to focus on the environmental and economic aspects of material selection, students indicated that the focus on social aspects of this module are important to them.

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References

[1] ABET, "Criteria for accrediting engineering programs effective for the evaluations during the 2019-2020 accreditation cycle" [Online]. Available: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2019-2020/#GC3/ [Accessed Feb. 3, 2020].

[2] M. Ashby, E. Brechbühl, T. Vakhitova, and A. Vallejo, "Social Life-Cycle Assessment and Social Impact Audit Tool: A white paper" in *ANSYS Granta Design*, 2019. [Online], Available: https://grantadesign.com/ teachingresources/papslcen19/ [Accessed Feb. 3, 2020].

[3] UNEP-SETAC, "Guidelines for Social Life Cycle Assessment of Products," *United Nations Environmental Program*, 2009. [Online]. Available: http://www.unep.fr/shared/publications/pdf/dtix1164xpa-guidelines_slca.pdf [Accessed April 9, 2020].

[4] N. DeJong-Okamoto, J. Rhee, and N. J. Mourtos, "Incorporating the impact of engineering solutions on society into technical engineering courses," *Global Journal of Engineering Education*, vol. 9, pp. 77-87, 2005.

[5] R. W. Welch, "*Humanities and social sciences within civil engineering curriculum," in Proceedings of the 2011 ASEE Annual Conference & Exposition*, Vancouver, BC, June 2011 [Online]. Available: https://peer.asee.org/180702011 [Accessed April 9, 2020].

[6] D. R. Berg, and T. Lee, *"Incorporation of liberal education into the engineering curriculum at a polytechnic," in Proceedings of the 2016 ASEE Annual Conference & Exposition*, New Orleans, Louisiana, June 2016.

[7] B. Przestrzelski, B., S. M. Lord, and M. M. Camacho, "Trash teachings: How a materials science module series about waste can empower engineering students to be more sociotechnically responsible," in *Proceedings of the 126th annual ASEE Annual Conference & Exposition,* Tampa, FL, June 2019. [Online]. Available: https://peer.asee.org/33465 [Accessed April 9, 2020].

[8] B. Przestrzelski, E. A. Reddy, and S. M. Lord, "Integrating experiential with technical: How materials science modules can help redefine the traditional engineering canon," in *Proceedings of the 125th annual ASEE Annual Conference & Exposition,* Salt Lake City, UT, June 2018. [Online]. Available: https://peer.asee.org/30684 [Accessed April 9, 2020].

[9] S. M. Lord, B. Przestrzelski, and E. Reddy, "Teaching social responsibility in a circuits course," in *Proceedings of the 2019 ASEE Annual Conference & Exposition*, June, 2019.

[10] L. Vanasupa, B. London, K. Chen, and R. Savage, "Curricula to educate the 2020 MSE engineering professional: Simple but powerful changes in the way that MSE is taught," in *Proceedings of the 2006 ASEE Annual Conference & Exposition*, June, 2006.

[11] C. Caron, "Starbucks to stop using disposable plastic straws by 2020," *The New York Times*, July 9, 2018. [Online]. Available: https://www.nytimes.com/2018/07/09/business/starbucks-plastic-straws.html [Accessed April 9, 2020].

[12] A. Wise, "American Airlines to eliminate plastic straws from cabins, lounges," *Reuters*, July 10, 2018. [Online]. Available: https://www.reuters.com/article/us-american-airline-straws/american-airlines-to-eliminate-plastic-straws-from-cabins-lounges-idUSKBN1K02SF [Accessed April 9, 2020].

[13] J. M. Harris, "Sustainability and sustainable development" in *International Society for Ecological Economics*, vol. 1, pp. 1-12, Feb. 2003.

[14] International Institute for Sustainable Development, "Life Cycle Costing A Question of Value," [Online]. Available: https://ec.europa.eu/environment/gpp/pdf/WP-LifeCycleCosting.qx.pdf [Accessed March 12, 2020].

[15] ISO 14004 - 14044 (1990 – 2006) "Environmental management – Lifecycle assessment – Requirements and Guidelines" *International Organization of Standards* [Online]. Available: https://www.iso.org/standard/38498.html [Accessed March 12, 2020].

[16] NOAA, "Trash talk: What is the great pacific garbage patch?" *Marine Debris Program* [Online]. Available: https://marinedebris.noaa.gov/videos/trash-talk-what-great-pacific-garbage-patch-0 [Accessed March 12, 2020].

[17] B. Lee, "Microplastics Found In The Ocean And In Human Poop," *Forbes*, Sep. 3, 2019 [Online]. Available: https://www.forbes.com/sites/brucelee/2019/09/03/microplastics-found-in-the-ocean-and-in-human-poop/#330e.