Integrating Experiential with Technical: How Materials Science Modules Can Help Redefine the Traditional Engineering Canon

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Integrating Social with Technical: "Bring in your Trash" module for a Materials Science Class

ABSTRACT
Traditionally, the engineering canon focuses solely on technical skills, but there is a growing demand for engineers who design solutions in from a sociotechnical perspective. This paper describes "Bring in your Trash" a module for a third year Materials Science course where students explore materials classification in hands-on way that connected to their everyday life with attention to social context. This module was successfully implemented in Fall 2017 with 31 students from General, Electrical, and Mechanical Engineering. Students brought in their own weeks' worth of trash. The first portion of class time focused on materials categorization and classification, engineering concepts they had been previously introduced to in class. A class debrief challenged students to think about topics related to recycling in general and their larger social responsibility in material choice as future engineers. In a subsequent reflection, students provided feedback, suggestions for improvement and articulated their meaningful takeaways from the module. Analysis of student responses shows that learning objectives were achieved. Lessons learned suggest improvements for future iterations of this module and adaption to other instructors' classrooms.

INTRODUCTION

As defined by Merriam-Webster, engineering is "the application of science and mathematics by which the properties of matter and the sources of energy in nature are made useful to people" (1). The technical nature of this definition continues into the canon shaping the engineering curriculum. While engineering education has traditionally focused solely on the technical skillset, there is a growing industry and academic demand for engineers who possess social and global values to better align with the changing industry (2) (3) (4) (5). Terminology such as 'socio-technical' engineering is becoming more common, as is the blending of the social with the technical in and out of the classroom. Leaders in engineering at Lafayette College believe, "Because technologies are designed by people, it follows that technologies are not divorced from the realities of human culture and our attendant moral and political concerns. Those non-technical aspects cannot be checked at the design door, as it were, nor held outside of the technologies engineers create." (2) The integration of the social context into traditional technical engineering curricula aims to produce engineers who are more socially responsible as well as better prepared for their careers.

The creative integration of social with technical contexts in the materials science and engineering classroom to assist student learning of broader concepts has been explored before. Baillie and Vanasupa creatively conjure contextualized scenarios for materials science students and faculty to dive into, exploring materials characterization, composites, polymers, semiconductors, and other traditional materials science topics (6). Others have tested formal in-class and lab activities that bring together 17th century cultural implications or team scavenger hunts with materials science topics in unique project-based learning experiences (7) (8) (9). Going beyond a national context of project-based learning, some have brought global challenges into the classroom to engage students that fosters a new responsibility to their engineering and science degrees and others are developing full courses to purposefully fold technology in materials science with ethics and social responsibility (10) (11) (12).

This integration of social context into the traditional engineering curriculum is also a focus at the University of San Diego, and is a subset of a project funded by the National Science Foundation (NSF) under the Revolutionizing Engineering and Computer Science Departments (RED) program. It is the larger goal of this work to empower student engineering changemakers through refinement of the engineering canon. It is also a goal of this work to develop content useful for other faculty so that incorporation into another's classroom, whether in part or in full, is not such an arduous task.

The purpose of this paper is to describe and assess the introduction of one creative social context module, "Bring in your Trash," into a traditional material science class. Details of design, implementation, and evaluation of the student response to the module are provided. This is followed by lessons learned from the instructors. Detailed instructor materials are available in the Appendix.

METHODS

Module Design

A module was developed by an interdisciplinary team of educators (Electrical Engineering and Materials Science, Bioengineering, and Anthropology), for a third-year level Engineering Materials Science course. This team included the instructor for the class, a tenured engineering professor, and two postdoctoral scholars, one with expertise in anthropology and the other in bio-engineering. All are familiar with active learning techniques in the classroom. This module was designed to creatively integrate social context and sustainability into the classroom while not forfeiting but complementing the required engineering technical skillsets. The inspiration for this module was an activity at Stanford University where the instructor asks students to create something with the trash they collected over a week, with the intention to inspire that creativity can come from anywhere (13). We adapted this activity into a module for a materials science third-year class, with the following learning objectives:

(A) Explain how material choice could be broadened beyond technical properties to include aspects of sustainability and human responsibility
(B) Classify materials based on property, cost, life cycle, and use
(C) Describe the need for further evaluation of materials beyond their properties in the design process.

The entire module was designed to include several activities as shown in Table 1.

Table 1: Breakdown of time for activities in the "Bring in your trash" module.

Pre-Class	55-minute Class Period		Post-Class
Instruction introduction (10 min)	Team Trash Material Classification (30 min)	Whole Class Debrief (20 min)	Individual Reflection (digital- no time restriction)

A week before the experimental class period, the instructor spent about 10-minutes to introduce students to the study and instructions for the week. Each student was given two items: (1) a medium sized trash bag to be filled with non-perishable and non-identifying trash in their living quarters and (2) an informative sticker shown in the Appendices. Students were instructed to complete the information on the sticker and place the sticker on their filled bag, which was to be brought with them to the experimental class period.

The in-class module was designed to include two major segments. The first segment focused on materials classification where student teams documented and assessed the sticker information for each of the bags to be sorted and then sorted their trash based on one of four assigned categories: (1) property, (2) use, (3) life-cycle, or (4) cost (see Figure 1 for the assignment cards that were distributed). This first segment of the class period is accompanied by a worksheet (Appendix) to be completed by each team.

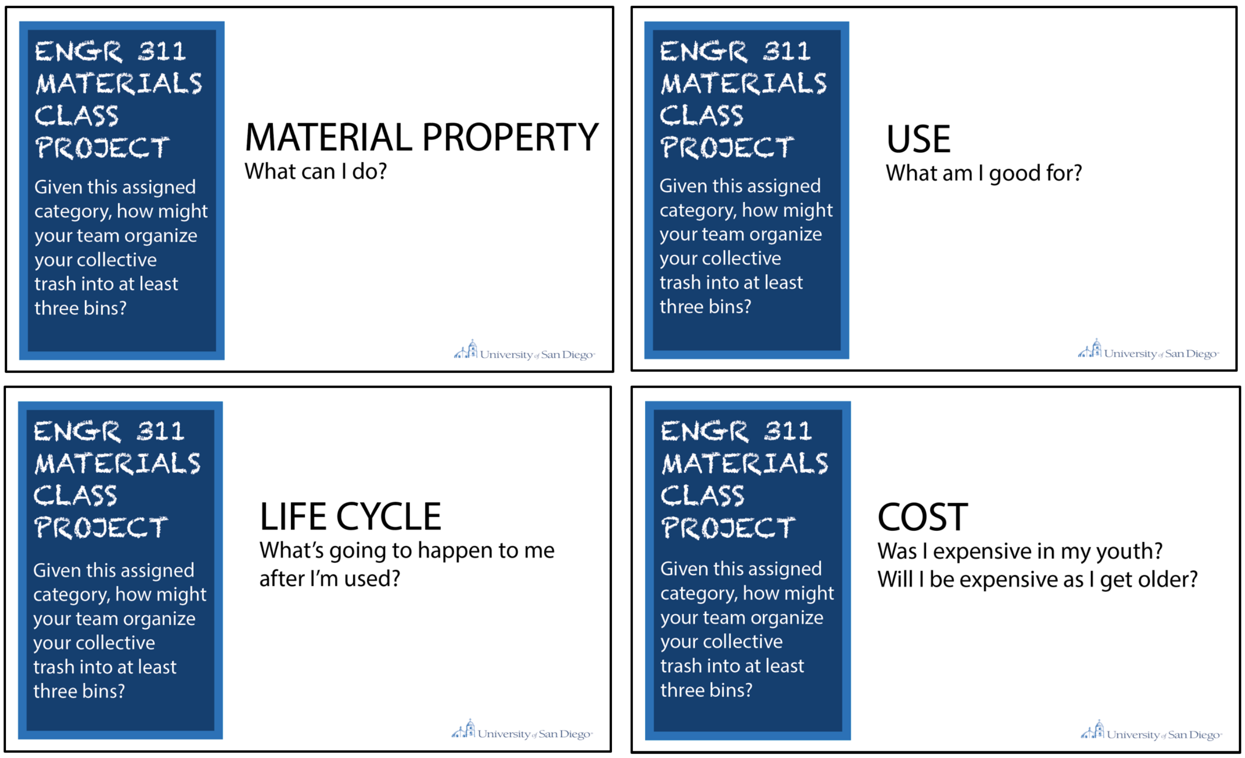

Figure 1: The assorted assigned category cards that were distributed to the teams. Each team received only one card.

The second segment of the class period included whole class discussion and debrief of the previous trash-sorting activity, starting with questions related directly to the trash sorting leading into larger questions of social context. After the class, students were invited to do an online individual reflection to be completed within a week of the class.

Module Implementation

Approximately 30 students from General, Electrical, and Mechanical Engineering collaborated with their peers on the in-class portion of the module during a 55-minute class period in Fall 2017. The activity was a required part of class. All students were invited to participate in the evaluation of the activity and those who wished to do so, completed an informed consent compliant with university-approved IRB policies.

Prior to the students arriving to class, instructors arranged the classroom space such that eight large rectangular tables formed a large oval in the room, atop which table numbers corresponded with team number assignment. As students entered, they were instructed to bring their filled trash bags to the front of the room where they formed a large pile, representing a week's worth of trash for 31 undergraduate students. As class began, this pile was referenced and reflected on as a symbol of a larger problem the world faces and served as a source of motivation for the activity.

Students formed teams of four around their assigned tables, and each student in the team was assigned one of four roles:

(1) Garbage Collector- retrieved one bag and one pair of non-latex gloves per person in the team (typically n=4)
(2) Recorder- completed the in-class worksheet
(3) Photographer- took pictures of the team's organizational structure and submitted them to the instructors
(4) Presenter- presented team's findings.

Students were instructed to look through a trash bag individually, recording the information on the sticker of each bag on the worksheet so that team averages could be calculated. The averages included the average number of days it took to fill the trash bags, the average number of humans to contribute to the trash bags, and the average estimated percentage of filled trash bags.
Once bag information was documented, students were asked to share their trash with their teammates. During this sharing period, each team was handed a card (see Figure 1) assigning them a category to use to categorize their trash contents. Students were instructed to, as a team, discuss ideas and choose one sorting scheme that contained at least three separate bins, the titles of which were to be documented on the worksheet as well as on index cards to be used as physical labels on their tables. Students then physically sorted their collective trash into these bins by distributing their trash beside the index card labels. The trash sorting period lasted ten minutes, after which time, teams recorded their work on their worksheets and captured photos of their final sorted trash.

The second segment launched with paired team presentations, where presenters shared their team's categorization with their neighboring team. After this, students and instructors formed a standing circle in the middle of the room to launch the first of the activity debriefs. The averages from team worksheets were discussed, regarding appropriate representation of trash of larger groups, asking who was represented in the room and who was not, and wondering how trash would differ for different populations. Other discussion questions included:

- How did you as a team decide what categories were most useful?
- How did you decide what went where?
- Any difficulties of placement of certain objects? If so, which ones and why might that have been?
- What was surprising to you about how your neighboring team categorized and sorted their contents? Anything different than how you might have sorted their contents?
- How did your team handle objects that didn't fit the categorization structure? How might we categorize future materials that don't even exist yet? Why might this be important?

Students were then asked to turn around to their tables, still remaining in the standing debrief circle, and identify one object from their team's trash contents. Each student was asked to then consider how might they, as an engineer, better design that material to better address one or more of the four categories (property, use, life-cycle, and cost). This analysis was done silently or with a partner, and aimed to launch the conversation around engineering responsibility, leading directly into the second activity debrief. All students came back together in the standing circle for discussion of five final questions:

- How much of what we were going to throw away this week could have been and still can be recycled?
- Why do you recycle? Or maybe, why don't you recycle?
- Why should we, as engineers, be concerned about recycling of materials?
- Why does categorization of materials matter?
- How might we, as engineers, design solutions that better fit categories? And why should we?

Following closing statements from students and instructors, instructions regarding the reflection assignment were given by the instructors. The reflection was to be completed individually, within a week of the class period, and would be digitally distributed after class. Instructors asked for volunteers to remain after class to help sort the recyclable items and reset the space to its original set-up.

Evaluation Process

After class, the instructors analyzed the team worksheets and collated the bins from each team. These categories were added to the second question of the reflection, which asked students to analyze their bins from class and state if, after seeing others' sorting and discussing larger impacts of trash in class, their bin sorting would change if asked to sort their contents once more. The collection of questions asked are below:

- Q1: In class, our group was assigned this category type: (A) Property, (B) Use, (C) Life Cycle, (D) Cost, or (E) I was not in class.
- Q2: What bins below would you use if you had a second opportunity to sort your trash using the SAME CATEGORY you were assigned in class? (A) Opacity, (B) Weight, (C) Cost, (D) Resale Value, (E) Perishability, (F) Transparency, (G) Use, (H) Rigidity, (I) Recyclable Components, (J) Biodegradable, (K) Material Type, (L) Other (add your own)
- Q3: Did your above bin selection change from the bin selection made as a team in class? (A) Yes, (B) No, (C) Other
  - If yes, describe how your second bin selection was different from that made in class. If no, describe why it did not change.
- Q4: If a friend or someone else who contributed to your trash bag asked you about the class on Friday, October 6 (the date module was implemented in class), what would you say?
- Q5: How do you think this "Bring in Your Trash" activity could be improved?
- Q6: What factors do you think you will consider as you make choices about materials in your future career as an engineer?

Once students completed their individual reflections, their participation in the module was complete. An additional class period featured a guest lecturer with expertise in reuse of waste products and some of these discussions were continued in this class, but no data was captured from this additional class period (14).

RESULTS AND DISCUSSION

Of the 32 students enrolled in the class, 25 digital reflection responses were submitted, two from students who did not attend class and therefore only answered the last two questions of the reflection. All others answered all of the questions.

Materials Sorting

Responses to the question of which bins students would use if they had a second opportunity to sort their trash are documented in Figure 2.

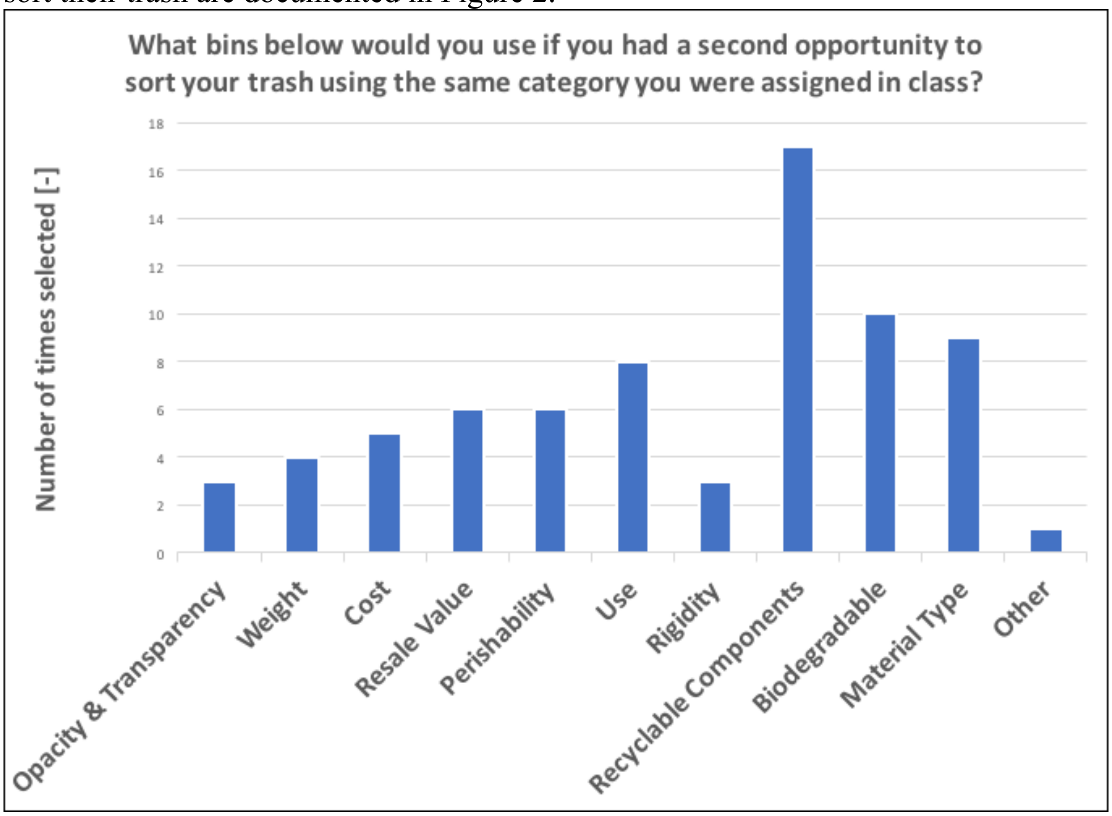

Figure 2: Student reflection on bin selection of choice if given another opportunity to sort their trash.

Students were able to select as many bins as they saw appropriate for a second sorting. Students selected as few as 1 bin or as many as 8 bins, with the average number of bins selected being 2.88 and the total number of bins selected by all students being 72. The most common bin selected was "Recyclable Components," selected by 18 students (nearly 25% of responses). The second most common bin was biodegradability (10 students; 14%), closely followed by material type (9 students; 13%), and then use (8 students; 11%). All other bins were selected by 6 students or less. Additionally, only one student chose to add a category of their own (Other), and this student's suggested bin was landfill, associated directly with the larger bin of recyclable components.

When asked if their "post-class bin selection differed from the bin selection made as a team in class," students were clearly split with 52% (12 students) stating "No" and 48% (11 students) stating "Yes" (their bin selection did change following the class sort, the debrief, and time to reflect). This question sought to evaluate if exposure to the class content/debrief and individual time to reflect would change how the students would sort their trash.

The next reflection question probed students' reasons behind their choices to resort or keep the same sorting strategy. Table 2 shows the responses for the students who would change their sorting strategy and Table 3 includes the data for those students who said their bin selection would not change.

Table 2:Reasons for choosing a new bin selection strategy for students who would change their bins. (N=11)

	Frequency of Responses [#]	Percentage of Responses [%]
Exposure to a different sorting option	5	45%
New perspective	4	36%
Forgot/didn't follow instructions	2	18%
Totals	11	100%

Approximately 45% of the students who would change their bins said this was due to exposure to a different sorting option, either during the in-class module (team trash sort, neighbor team share, or whole class debrief) or during the time after class prior to the individual reflection. Examples of responses coded in this category include:

> "A bin that we did not select during the [in-class] activity was biodegradable. I think that bin would be more useful when talking about life cycle, than the original bin of metals that we had."
>
> "I added resale value, considering we didn't have any resale items in our collective trash we didn't use this bin [during class]."

Other students (36%) gained a new perspective which led them to change their bin selection from class. Example responses coded in this category include: "Our selection of trash was not uniform, and we had no idea of what we were doing. Now I look at this all differently." or "[T]he concept of cost and recyclability made me contemplate the business side of reusing and recycling valuable materials. If the materials have value then it will motivate business to lifecycle; likewise we may engineer with a reusable/lifecycle mindset." Some of these students specifically mentioned they experimented within the spectrum of the assigned category: "It was different because our group had life cycle, and we separated groups into the different materials that have different lift cycles to consumers. This time around, I changed it to the ones that characterized the materials into life time in a dump."

Finally, two students forgot what they did in class or did not follow directions. “My team did not realize our card said, ‘Use,’ so we sorted according to material. If we did this activity again, we would definitely have sorted our materials differently.”

Table 3: Reasons for choosing a new bin selection strategy for students who would NOT change their bins. (N=12).

	Frequency of Responses [#]	Percentage of Responses [%]
Everything already fit our bins	5	42%
Could not find a better bin	3	25%
Team agreement on definitions	1	8%
(Actually) did explore other bins	1	8%
No description given	2	17%
Totals	12	100%

Among the students who would not change their bins, the most common reason was that their contents during class were sorted into appropriate bins and did not need resorting. This suggests comfort with their initial responses perhaps due to careful consideration. However, it could also indicate a lack of creativity or willingness to expand one’s knowledge to include more options or lack of engagement. Examples of responses coded in this category include: “We thought we had a great way to sort the bins already.” or “The above bins are easily observable and everything in our trash bag fit definitively int[o] a bin.” The second most common reason for not changing bins was not finding a better bin listed in the options provided. While there was an “Other” (write-in) option for students, it might have gone unnoticed by this group of students. An example response coded in this category included: “Because in the same category of property, I can hardly find a really different bin.”

Improvements to the Module

Student suggests for improving the activity are summarized in Table 4.

Table 4: Students' suggestions for improving the module activity.

	Frequency of Responses [#]	Percentage of Responses [%]
Pre-class rules	10	34%
Clear expectation regarding recycled items	4	14%
In-class exercise structure	3	10%
Additional exploration (another follow-on class/exercise)	3	10%
Even more emphasis on responsibility of the engineer/use in future work	3	10%
Space	2	7%
Make it less experiential	2	7%
Relatability to 311	1	3%
None	1	3%
Totals	29	100%

The most common suggestion for improvement related to clarifying the rules that were communicated prior to the class. Largely focused on the restrictions of what could be brought in as trash, many students commented on the repulsiveness of the trash due to others not following the instructions. "I think the rules for what trash to bring should have been stricter." and "Make sure people follow directions and do not include blood, bodily fluids, maggots, flies, food, hair." and "Ensure better means of sanitation and standardization of the trash could have been implemented." One student felt the pre-class instructions were clear, but rather, "people need to follow instructions better." Four students indicated a frustration at the lack of clarity of the pre-class instructions, most specifically the expectations regarding recyclables. Several students felt that the instructions did not allow them to most accurately practice their normal recycling habits. These students did not produce much non-recyclable trash in the assigned week, but for fear of not completing the assignment, filled the bag with items they might normally recycle, thus engendering greater emphasis be placed on recycling in class than might have been necessary had the instructions been clearer. Examples of such responses are:

> The trash collected is not an accurate account of an individual[']s waste. For instance I cook with a lot of fresh meat and vegetables, I had to leave out almost all of my trash (fat from steak trimmings, the base from lettuce heads, lots of egg shells, pineapple...). The only trash I was able to bring in was trash I would of put into the recycling if I didn't have this assignment. Maybe the assignment could be flipped, tell the groups of students to put recyclable trash aside that they think applies to their topic. Or take a picture everyday to show the trash that was excluded by the rules.

> Really highlight the fact that this should be your average trash, and to put recyclable items into the recycling bins rather than the trash bag. I don't think a lot of students, including myself, understood that so we just put all of our trash (including recycling) into the trash bin, thus making it seem as though we produced more trash than we actually did.

Several students (10%, 3 students) recommended an additional exploration of the topic, by way of a follow-on class, or exercise, or field trip to the dump.

> Learning more about how materials we would be using in our own engineering and how they can be more sustainable.
> having students put all of the recycling into bags after the activity and taking it to the recycling bin. In reality, most of those items that were brought were probably not going to be recycled in their homes and it is nice to know that now they definitely were recycled."

These responses suggest that the students possessed particular interest in the topic, and sought additional exposure to the experiential work from class. Others (7%, 2 students) felt differently and desired a less experiential activity: "Having the participants make a list of their own trash bag instead of actually having to bring the trash. This way items won't be left out from the discussion and participants won't put recyclables in their trash just to fill it up." and "By presenting it to a younger audience or just by making the point in a lecture." Three students expressed concerns regarding the structure of the activity and made recommendations:

> Have everyone go around and put notes on each one then at the end have everyone run in set notes (sic)
>
> The activity felt right until we got about halfway through the circle/reflection activity. The discussion lost structure and turned into people sharing semi-relevant anecdotes about a video they saw or something they knew. The activity would benefit from having more concrete questions/direction during that section or even moving into a different reflection activity or presentation.

One student suggested, "Evaluate our own trash" which references the in-class method that the students anonymized their trash and sorted others' trash

Three students felt there could be more emphasis placed on the responsibility of the engineer and how these students might be able to utilize this material in their future work: "Emphasize the aspect of the exercise is to show that engineers make everything that we throw away." This suggests that the message of engineering responsibility of material choice was captured during class by these students, and that they wanted to be sure their classmates' also grasped the concept. This is promising and exciting for the future of activities like this.

Students also had a place for any additional optional comments in the reflection survey. Three students included useful feedback in this space. One student said, "I liked this over a homework assignment." Another commented on the active-learning style of the classroom, "Standing is great." Another student said, "This activity was really fun and interesting. I appreciate that you all take the time to make this happen. Thank you!!"

Sharing Takeaways

Students were also asked to reflect on what they might share about the class if they were asked by a friend. A variety of responses were recorded from the 25 students, all of which were coded into eight categories as shown in Table 5.

Table 5: Items that students would share with a friend who asked about the "Bring in Your Trash" module.

	Frequency of Responses [#]	Percentage of Responses [%]
Sorting materials	10	20%
Seeing the impact of waste	8	16%
Recycling exposure	8	16%
Examining waste habits	7	14%
It was fun/interesting/different	5	10%
It was gross	5	10%
The engineer/human responsibility	4	8%
Class was nothing novel	3	6%
Totals	50	100%

Reponses to this question were more in-depth than previous questions and required multiple codes to be assigned within each student response. The average number of categories coded for each of the 25 responses was 2.17, with some responses only receiving one code and others, especially those that were longer, receiving as many as 5. The most common code was "Sorting Materials" which appeared in 20% of the responses (10 instances). Students heavily gravitated towards describing the class as sorting materials, some described the effect it had, and others added detail about the class itself. Examples of responses that were coded as "sorting materials" are: "It was something different. … We had to sort trash in order to learn about our impact." or "Would tell them about how to categorize trash."

The next two most common coded responses were seen in 16% of the responses, "seeing the impact of waste" and "recycling exposure" both of which indicated slightly deeper learning and extraction of information than the "sorting of materials" code. Two example responses that connected both codes are as follows: "I would tell them that our class produced a lot of trash as a whole and that I think we should work to reduce our waste as well as to reduce, reuse, and recycle." and "It went good, people REALLY need to wake up to recycling and composting and be mindful of their footprint and waste." One was not coupled with recycling exposure: "'I'm in a materials science class for engineering and Dr. Lord wanted us to bring in trash for a group project on Friday. I think it's something about how much trash we generate maybe.'" Approximately 14% of the responses (7 instances) would tell others the module had them "examining their waste habits". All of the responses that were partially coded as "examine waste habits" were also coded with others, most commonly "sorting materials" or "recycling exposure" or "seeing the impact of waste". Some examples of the responses that were designated with the "examine waste habits" (alongside others) are: "I would say we sorted the trash to discover how a majority of the trash can be recycled or put to other uses." or "We are observing our trash in order to understand how different materials impact our everyday lives." Or

> We analyzed the material properties of our trash to reflect on the current materials being used all the time, as well as reflect on how much trash we use in a week and see the need for more recyclable products in order to convince consumers to recycle.

The next two most common coded responses were "it was gross" and "it was fun/interesting/different". Some of the students could not get past the visceral experience and simply described their experience as such: "Nasty" or "No food in the bag please, gracias". Others acknowledged the visceral experience and were able to also state a deeper takeaway: "I would tell my friend that the air kinda stunk in Cymer [the space used] and that the activity made me think about recycling." For those who thought "it was fun/interesting/different", these responses were always coupled with additional codes, most commonly "sorting materials" or "seeing the impact of waste", suggesting that those who believed the module to be fun, interesting, or different, also took away deeper meaning of their impact in addition to the surface level sorting of materials.

Approximately 8% of the responses included a mention of "engineering or human responsibility" which suggests a more personal and deeper takeaway from class by these respondents. All of the students who mentioned this larger responsibility also coupled with other codes, most commonly "seeing the impact of waste" or "exposure to recycling": "I would say that we explored the reality of our consumer waste and how as engineers we could do something to change it." or "I would tell them that the exercise caused the class to think about recycling and what limitations and improvements could be made as engineerings. (sic)" These responses as well as those which were presented previously are promising takeaways from the class.

One final grouping of responses (6%) did not see the class as novel and would have a difficult time sharing with others about the class: "it was gross and I wasn't told much I didn't already know." While promising that this only occurred in three responses, it is the goal to reach all students. While this particular question might not have extracted useful takeaways the students would be willing to share with others, a final question regarding the factors they will consider as they make material choices in their future engineering careers might have (Table 6).

Material Choices in Engineering Career
Table 6: Students identified what they would most consider as they make choices about materials in their future engineering career.

	Frequency of Responses [#]	Percentage of Responses [%]
Life Cycle (Recyclability/Biodegrabability)	20	41%
Cost	9	18%
Environmental impact	8	16%
My contribution	7	14%
Ethical material access	4	8%
Amount of material used	1	2%
Totals	49	100%

Responses to this question also required multiple codes to be assigned within each student response. The average number of categories coded for each of the 25 responses was 1.96, with some responses only receiving one code category and others, especially those that were longer, receiving 3 or 4. The most common code was "Life Cycle (Recyclability/Biodegradability)" which occurred in 40% of the responses (20 instances). Some responses only received this code: “I will definitely consider the entire life cycle of all materials” or “The materials I would consider is if it is biodegradable or it can be repurposed for the same use that it is intended for. (sic)” or “Make sure it can be reused for other engineering projects!”. Other responses were coupled with codes such as “Cost” and “Environmental Impact”: “Obviously materials are super important in any design process, so I believe I will look for materials that are readily re-usable and not super harmful to make all the while being extra cheap.” and “I enjoy thinking about long-term outcomes for materials. In 50 years will we be able to reuse or salvage plastic used in our electronics? Probably not but things could be designed in the future that consider this.” and “The impact they have on the environment, such as whether they are recyclable/biodegradable or whether you know they will end straight up in a landfill.” and “I will make designs that incorporate parts that are either biodegradable or that can be reused for other applications so that I have a smaller impact on the environment.” One student in particular discussed the conflicting relationship of material life cycle and cost: “Although the relationship between cost and life cycle of the material often are seen as conflicting, I believe there is a way to make products that are cost efficient as well as being good for the environment. It is just a matter of putting in the time to focus on possible materials that can do both.”

Others (14%) specifically mentioned themselves and how they will consider their contribution both now and in the future. These responses always coupled with another coded area, most commonly “life cycle” or “environmental impact”, suggesting that these students feel their contribution is directly connected to the life cycle of materials and their environmental impact. Examples of these responses include: “The impact my materials will have on the planet.” and “That people have to sort through the things I do not separate properly” and “design with purpose so it doesn't harm the environment now or in the future. Take long term cost into account. Not just immediate cost.”

Some students specifically mentioned ethical access of materials (8%) and mindful management of how much material would be used (2%) intertwined with previously presented codes like “life cycle” and “environmental impact”: “Whether they can be reused and whether you can get the material in an ethical way.” and “Cost, amount of material, access to certain materials, environmental-friendly ratings” and “Which field of engineering I'm in and what my choices are.” These student responses suggest a broader range of understood consequences associated with management of materials in engineering.

What worked well

The instructors were surprised at the volume of and variety of trash produced by the students in a week. The instructors felt seeing the week’s worth of trash generated by the students themselves was a very powerful image when the bags were all grouped at the front of the room. Though some did not follow the instructions for non-perishable items (as was previously brought up in the student data), each student brought a bag, some bursting and some containing only a few items. During the session, one of the instructors noted that students had visceral and powerful relations to the trash. The students saw it as not being sanitary, as messy. They said, “gross” and “come take a picture of what someone threw out!” That failure to follow instructions was a learning moment where the students confronted the trouble of processing waste and recycling.

One of the instructors observed that some students dove into the activity headfirst, sorting rapidly (some in too much detail for the allotted time), many laughing, some claiming theirs and their roommates' trash from across the room, discussing their waste habits, and others wondering aloud, "Why would someone throw this away?". The instructors see this as content to incorporate in the debrief in future iterations of the module, most specifically introducing the concept of reuse. What one student might be throwing out might be just what someone else needs. This was discussed in the subsequent class facilitated by an expert in waste reuse expanding beyond the student context to communities where one person's waste might be vital to the survival of another person.

The energy in the room and out of the room was evident. Before the class began, students in the class were anticipatory, eager to see what was to be done with the trash that they had collected. Students walking by the classroom, which has glass walls, looked in, intrigued by the different activities happening inside.

When reflecting on the overall participation of students in the room, the instructor who teaches the class noted that several students who don't often contribute in class were amongst the top participants in the active sorting and following debriefs. In particular, several males of color contributed actively during the debriefs of the "Bring in Your Trash" module, varying a great deal from other class time.

As the importance of social contexts became more prominent in the debrief, several reactions of the students were noteworthy. When prompted with "how often do engineers make decisions about material choice for product development and other processes?, one student exclaimed, "All. The. Time." The discussion that followed was rich, discussing the cognizant role of the engineer. There was also shock and surprise associated with several students' responses to their hearing that designing for sustainability is their responsibility as engineers. One student in particular exclaimed, "but that's a lot!" to which peers responded "yes and, what happens if we don't start now?"

Areas for Improvement and Some New Ideas

As was mentioned by one of the students in the post-class reflection, the conversation in the debrief came to a lull about halfway through, at which time, students started sharing specific and personal tales. The instructors feel there is room for improvement for facilitation of a long debrief or altering the structure to shorter, smaller debriefs prior to a large, whole-class debrief.

Clarification of rules for contents of trash must be done on the next iteration. In addition, careful consideration is needed about the trash itself and how it can be more evenly distributed among the teams. Some teams had too much trash to sort through in the allotted time and others did not have enough. Questions under consideration include Does everyone need to bring in their trash? Does a full week produce too much trash to be sorted within a 55-minute class period? Many students did mention that their bags were filled with recyclables because they "had to fill the bag"—how might the challenge be better framed to include or exclude recyclables?

Instructors collectively believed the activity might have been over-structured in certain areas. The assigned roles for the teams (garbage collector, presenter, recorder, and photographer) became confusing for the students. The four roles were decided upon right before the class period and might not have been explained clearly. One instructor attributed some of this confusion to student lack of willingness to participate in ways they had not been exposed to in a classroom before.

The assigned categories for sorting were also an area of improvement seen by the instructors. Many teams took the category assignment more as a suggestion, and instead sorted by their own categories. Most of the time, in these cases, the students defaulted to material type. One instructor believed this might be due to the confusing nature of the assigned category, and hopes to make the categories clearer to the students in future iterations.

Time management was also an area for improvement, as time seemed very rushed at the beginning of class during the sorting and materials classification. Time then slowed down during the debrief to a point where it was noticeable and uncomfortable for the students, such that there was less discussion than expected by the instructors. The instructors hypothesize that these two occurrences are linked by time management- and suggest to spend more time in the beginning of the module, allowing teams to sort and also receive feedback (which was not carried out in this iteration). Because students felt rushed, they might not have had the time to develop the thoughts and insights that were to be delivered and discussed in the debrief. Future iterations will include more time for assessment and feedback of the classification systems to reduce potential impressions of disconnectedness and unjustifiable classification that might have been given. Music could have been utilized to signal team work time versus class discussion time. This might help with overall time management and make activities more fun. Additionally, with better time management, student help in the room could have been better utilized to assist with sorting, cleaning, and resetting the room at the end, rather than just the few student volunteers who were available.

The role of the photographer on each team was to submit photographs of the teams' final sorted trash. However, there was lack of instruction regarding the pictures to be submitted and therefore the products were of great range in utility. On some, the bin labels were clearly visible, while others, deciphering where the sorting began and ended was difficult. Future iterations will include more specific instructions for the photographs to be submitted.

The worksheet designed for the student teams to complete during class was inappropriately focused. While students were instructed to do both, many teams spent their time writing down what items went where on the worksheet and did not finish physically sorting their trash contents. The physical act of sorting trash is likely more impactful than listing the contents. In the future, the worksheet will focus less on listing the objects in the bins and more on the categories themselves, allowing for greater time spent on physical sorting of the trash contents.

When multiple instructors are in a room, roles can sometimes be unclear and confuse the students. While the three instructors had specific roles, this was the first time they worked in a classroom together. One instructor did not feel entirely comfortable intervening in the class to check in with the students who were being disruptive or non-participatory, and felt that overall, their contribution as an instructor could have been more fully utilized. It is important that instructors implementing active learning structures be comfortable as a team, and discuss handling ambiguity ahead of the class time to assist in the delivery of the content.

The instructors agreed with the students that improvements could be made in module structure. Upon seeing the frustration of students in regards to the unclear pre-class instructions with respect to recyclables, all instructors feel the need for revised pre-class instructions to make clear the answer to: What do we do with our recyclables? Additionally, the post-class digital reflections were surprisingly brief. This might have been influenced by the lack of clear connections made in class. One instructor noted, “Students can find making connections that I find straightforward to be deeply challenging. I wish we had given them more scaffolding to start making leaps themselves. That might have meant more discussion time, or more directed discussion among groups before we reassembled for shared discussion.”

The categories for sorting were handed out almost secretively during the class. One instructor is curious if playing up this portion of the activity might have an effect on student ownership of the activity. Maybe the distribution of cards could be accompanied by class-level brainstorming of bins which would provide further direction with clear examples of potential sorting models. Once the students did begin sorting, they seemed to be admiring each other’s systems of sorting. Perhaps this could be capitalized on in the module. The free form neighbor team share might be a place for more facilitated conversation. One student suggested, “Emphasize the aspect of the exercise is to show that engineers make everything that we throw away.” How might we better design a follow-on activity such that more of our students are coming to this realization on their own?

Some students found the activity “nasty”. Future iterations will cover the tables in butcher paper and have cleaning supplies on hand at all times. Additionally, instructors were a bit underprepared for how many students felt disgusted by the activity. Instructors feel that this could have connected well with some learning goals and hope to more formally address this in future iterations with additional learning goals and/or debrief questions targeting this powerful visceral response.

CONCLUSIONS

The collection of student responses and instructor lessons learned following the “Bring in Your Trash” module in the Engineering Materials Science course details a larger conversation around the experiential integration of social contexts into the traditionally technical engineering class. The module was successfully implemented in the classroom in Fall 2017 and future iterations will be shaped from the data discussed above. Analysis of the student responses showed learning objectives were achieved. Students were able to A) Explain how material choice could be broadened beyond the technical properties to include aspects of sustainability and human responsibility (B) Classify materials based on property, cost, life cycle, and use, and (C) Describe the need for further evaluation of materials beyond their properties in the design process. Following their exposure to the module, students were able to express a variety of social contexts to consider when making decisions about materials as future engineers. Overall, it was found that a module that blended the social with the technical content in a materials science classroom could be done, and with future improvements can be utilized in other classrooms.

ACKNOWLEDGEMENTS
The authors wish to thank the National Science Foundation's REvolutionizing Engineering and Computer Science Departments (RED) program through Award #1519453 for funding of this collaborative effort. The views expressed herein are solely those of the authors. We also thank the University of San Diego engineering faculty and students for their willingness to experiment with us in the classroom, especially our colleagues Dr. Ming Huang, Dr. Chell Roberts, Dr. Michelle Camacho, Dr. Rick Olson, and Dr. Leonard Perry for their support.

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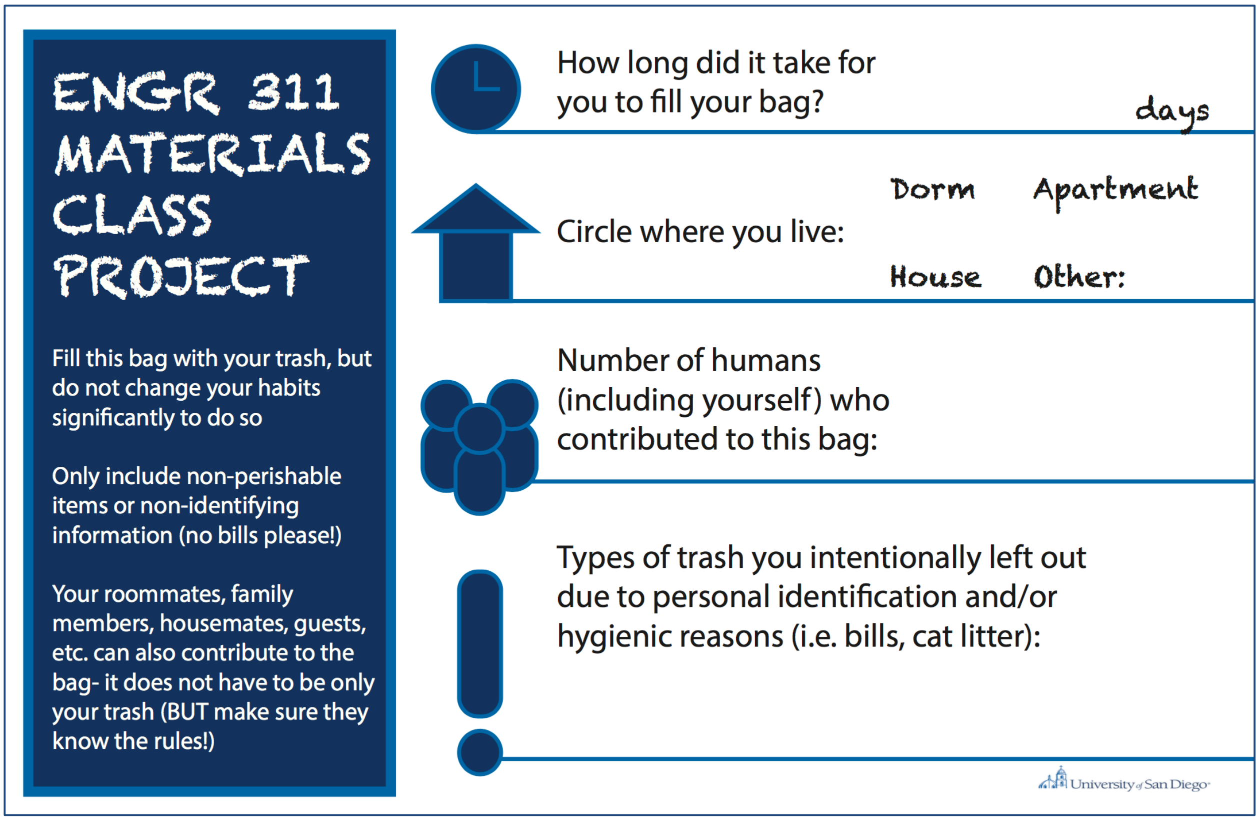
APPENDIX

- "Bring in Your Trash" bag sticker
- "Bring in Your Trash" team worksheet
    - Page 1
    - Page 2

"Bring in Your Trash" bag sticker



ENGR 311 MATERIALS CLASS PROJECT

Fill this bag with your trash, but do not change your habits significantly to do so

Only include non-perishable items or non-identifying information (no bills please!)

Your roommates, family members, housemates, guests, etc. can also contribute to the bag- it does not have to be only your trash (BUT make sure they know the rules!)

How long did it take for you to fill your bag? days

Circle where you live: Dorm Apartment House Other:

Number of humans (including yourself) who contributed to this bag:

Types of trash you intentionally left out due to personal identification and/or hygienic reasons (i.e. bills, cat litter):

University of San Diego

"Bring in Your Trash" team worksheet (Page 1)

TEAM #: ______ "Bring in Your Trash" ENGR 311

ENGR 311 aims to explain the importance of materials science in everyday life. This exercise seeks to connect ENGR 311 concepts to everyday life through exposure to experiential learning and group discussions that conclude with an individual reflection.

Start by documenting your team number (top of worksheet) and assigning roles per teammate. If less than four people are present in your team, the garbage collector and the photographer can be played by the same teammate. *When instructed, send pictures to [redacted]

Role	Recorder	Garbage Collector	Photographer*	Presenter
Name				

Document the information obtained from each sticker attached to each individual trash bag and estimate the percentage (0% to 100%) that each trash bag is filled. From these values, generate the profile of your team's average trash bag. Finally, document what the approximate average trash generated per person per day for your team's trash.

	How long did it take for [your person(s)] to fill the bag? [days]	**Number of humans who contributed to the bag [#]**	**Estimated percentage of trash bag filled [%]**
Bag #1			
Bag #2			
Bag #3			
Bag #4 (if needed)			
Team Average	C	B	A

Average trash generated per person per day:	$\frac{A}{B \times C}$	

1

“Bring in Your Trash” team worksheet (Page 2)

TEAM #: ______ “Bring in Your Trash” ENGR 311

TRASH SORT

You and your team have 3 minutes to sort through your trash individually. Consider what items could be categorized together. Briefly share your trash with your teammates.

You have been handed a Category Card. Circle your assigned category:

Property | Use | Life Cycle | Cost

Given your category, what bins might you create to sort your trash? Discuss some and decide on one system that has at least three unique bins. Write these bin names and short description below in table and on individual index cards, to be placed on your table where your team will physically sort the contents of your trash. List the contents physically sorted in the bins below:

Bin #1: ___________ ________________	Bin #2: ___________ ________________	Bin #3: ___________ ________________	Bin #4: ___________ ________________ (optional)
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	Bin #5: ___________
-	-	-	________________
-	-	-	(optional)
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	

2