Introducing Social Relevance and Global Context into the Introduction to Heat Transfer Course

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Abstract
Leaders, researchers, and educators have advocated moving from educating engineers in a way that reinforces that engineering is a purely technical endeavor to one that recognizes that it is sociotechnical, and happens in a global context. As part of a National Science Foundation - funded project, our engineering program is exploring ways for engineering educators to do this within required engineering courses. In this paper, we present an example of how content related to sociotechnical and global context was integrated into a required senior-level Heat Transfer course in mechanical engineering. We describe the design of the Social Relevance and Global Context Module and its use with students in Fall 2017. The module is designed for use in the Heat Exchanger section of the course. It is framed around a student-faculty project previously developed at our university and implemented in the Dominican Republic to provide affordable water heating for rural communities. First, students are presented with a quantitative problem related to the technical design of this water heater e.g. calculation of needed pipe length given other specifications. Then, they participate in a series of in-class activities designed to draw their attention to the context of this problem and additional design considerations for such a water heater. Finally, they write a memo in which they explore implications of contextual issues for the design of a water heater in different countries and consider other applications of course concepts. Together, these strategies can help students develop their skills with Heat Transfer calculations, consider Heat Transfer in sociotechnical and global context, and see the relevance of their Heat Transfer knowledge for other projects. Recognizing that instructors have many demands on their time, our module is designed to be easy to use and include activities for class and homework. Detailed instructor guides and materials are available in the Appendix so that other instructors could easily incorporate this module in their classrooms. We hope these examples might help other instructors incorporate these important themes into their Heat Transfer courses enabling more engineering students to include broader considerations in their engineering practice.

Introduction
Learning to consider the broad context of their work can help engineers develop better solutions. These solutions may also be more sustainable, economically feasible, and socially just and make positive change in the world. Helping students recognize that engineering itself is sociotechnical and consider the global context of their work is a goal of both University of San Diego and an element of ABET requirements [1]. It is also a significant challenge. Material that addresses these issues can be challenging to integrate into many traditional engineering courses.

Faculty at the University of San Diego's Shiley Marcos School of Engineering are developing new ways to meet this challenge. In recognition of the University's work in social innovation, peace studies, humanitarian engagement and sustainability, it is recognized as an Ashoka Changemaker Campus [2]. The Shiley Marcos School of Engineering has developed synergistic efforts with this University-wide commitment. Through the "Developing Engineering Changemakers" project, funded by NSF's REvolutionizing Engineering and Computer Science Departments program, the University of San Diego is becoming a national leader in the development of new curricula to meet the challenge of helping current students become effective engineers.

We are developing the Social Relevance and Global Context Module described in this paper in light of other efforts to develop innovative coursework for Heat Transfer classes. Research has shown that nontraditional pedagogy in Heat Transfer can develop student knowledge of a fundamental topic in mechanical engineering with complex and urgent sociotechnical implications [3]. It can also support the success of populations often underrepresented in engineering with liberative pedagogies [4] or provide them with opportunities to become more aware of their roles as engineers through service learning [5]. Our module aligns with ABET outcome h which requires supporting the “broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context,” which can be challenging to engage in traditional engineering classes. DeJong-Okamoto, Rhee, and Mourtos identify skills students need to be able to evaluate the impact of their solutions in a global/societal context and describe examples of course design elements that help students develop these skills that are incorporated into required and elective thermal/fluid courses [6]. The Social Relevance and Global Context Module explored in this paper presents a practical means of integrating social context into an engineering classroom, specifically for heat transfer. Materials and details are provided so that other instructors could easily incorporate this module into their classrooms.

Research on engineering in practice indicates that solving engineering problems successfully is not only a matter of technical skill. Engineers must be sensitive to the sociotechnical nature of their profession and the context of their efforts to develop and implement workable, appropriate solutions [7], and that failures to do so can have consequences for their technologies [8]. While ability to reflect on the context of engineering solutions is associated with their success in the profession [9], training students to do this—and doing so in ways that are well-integrated into the rest of a course—is by no means easy. As historian Atushi Akera has pointed out, although current ABET criteria would ideally be considered a space for supporting educational innovation, these criteria are often just another set of requirements that educators must develop strategies to meet [10]. Indeed, ABET’s shift to focus on students as emerging professionals has valuable outcomes [11], but includes many challenges for educators [12].

Engineering education scholars Juan Lucena and Jon Leydens suggest incorporating contextual detail into more traditional technical problems that students are presented with. They propose doing so by asking traditional technical questions in ways that require students to interrogate potential circumstances of problems they are given in class [13]. This can be done in ways that do not forfeit the technical requirements demanded of an engineer, but rather complement learning in the classroom to better mirror (and prepare students for) the socio-technical work necessary for acting as Engineering Changemakers or, simply, for successful careers in engineering.

This paper details the first iteration of a module to incorporate contextual detail in traditional technical problems that we are developing as part of a Heat Transfer course in Mechanical Engineering in University of San Diego’s Shiley Marcos School of Engineering. Here, we describe the design and integration into the course and evaluate the results using student memos and classroom observation. Based on this analysis, we have developed further plans for module development. Detailed instructor guides and materials are available in the Appendix.

Course Context

Student Population

In Fall 2017, 28 students were enrolled in this section of a Heat Transfer course, including 5 women and 23 men. Two of these students were simultaneously enrolled in courses designed to deal extensively with engineering praxis that engages social justice, humanitarian goals, peace, and sustainability. These are taught by other faculty members in the Shiley Marcos School of Engineering but supported by the same "Developing Engineering Changemakers" project that framed the course module described here.

Course Overview

Mechanical Engineering 400: Heat Transfer is a required mechanical engineering course taken by students during their senior year. This course covers the basics of conduction, convection, and radiation heat transfer with introduction to heat exchanger analysis and design, along with other applications. As stated on the course syllabus, this course is designed with learning outcomes including knowledge about steady and unsteady one- and two-dimensional heat conduction, internal and external convection, and basic concepts of radiation. In addition, the course is designed to teach students problem solving skills in energy-related areas and to understand the role that heat transfer plays in everyday life.

This course was primarily taught by the lead instructor, a mechanical engineering professor. Three additional faculty were involved in the development of this module. One is a professor with expertise in engineering education and electrical engineering while the other two are post-doctoral research associates with backgrounds in social science and bioengineering. This multidisciplinary team worked together to design the Social Relevance and Global Context Module presented in this paper, and the two post-doctoral research associates led the experimental class and performed data analysis.

Module Description

The Social Relevance and Global Context module was designed for integration in the Mechanical Engineering 400 course, to be used in the Heat Exchanger section of the course, near the conclusion of the 16-week semester. It is framed around a student-faculty project that was previously developed at our university and implemented in the Dominican Republic (DR) to provide affordable water heating for rural communities [14]. This module has three parts:

1. Pre-class homework: Technical Calculation
2. In-class activity: Designing Beyond Ourselves
3. Post-class memo: Reflections on Contexts

1. Pre-Class Homework: Technical Calculation

A week prior to the experiential class period, students were presented with the project goal: to design a solar thermal water heater based on the thermosiphon model. A schematic (Figure 1) of the system was distributed by the lead instructor, who provided additional project specifications and assumptions to be made:

1. The collector is made of a PVC tube array (21.33-mm outside diameter or ½" standard size PVC pipe). The tank is painted black and situated above the PVC solar collection

tubes (also painted black for maximum sun energy absorption) and to be located outdoors.

2. The design is based on the following assumptions:
   a. We would like to raise the water temperature by 12 degrees Celsius.
   b. Average time duration for active water heating each day is 5 hours.
   c. Tank size is 114 liters. The design is based on a goal of providing a five-minute shower at a flow rate of 1.2 gallons per minute (4.54 L/min) for a household size of five (two parents and three children).

Students were asked to come to the experiential class having started their hand calculations for this problem so that they were familiar with the technical details of the problem.

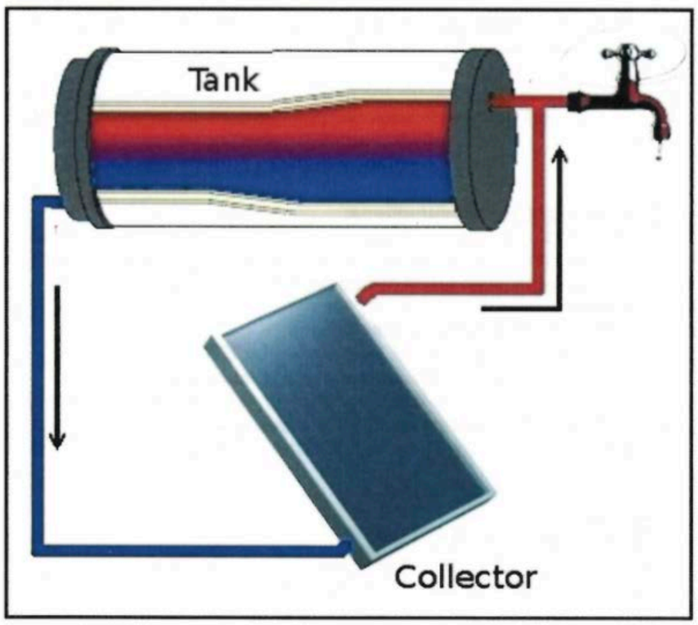

Figure 1: A schematic of a thermosiphon solar water heater model.

This portion of the Social Relevance and Global Context Module was paired with an in-class activity that introduced contextual design considerations and led students through a brainstorming exercise to explore context further.

2. In-Class Activity: Designing Beyond Ourselves

This activity took place over a 55-minute class period, and was led by the two post-doctoral research associates. The class period was broken down into two major components. In the first, students reflected individually on their own showering practices. In the second, they participated in a team activity that challenged their assumptions regarding the solar water heater system they had been tasked with designing.

Students were first asked to individually reflect on their own showering practices to highlight the variety of ways people might use hot water and to get them ready to think about the assumptions they might be making about showering and how the water heaters that they had already begun making calculations about might be actually be used. The facilitators guided these students through this 5-minute reflection with prompts and questions to consider such as, “Do you prefer to take showers in the morning or at night? After or around specific activities? How about water temperature? Water pressure? Must you arrange shower schedules around several roommates?”

Figure 2: A drawing that a student made to document showering habits

Students had a variety of responses. One example student work produced during this short reflection time can be seen in Figure 2. The following notes accompanied this image:

> Shower every day for about 5-10 minutes, including time to allow the water to heat up. The pressure is not that high and always have the overhead fan on in case of steam. Shower twice a day after exercising and sweating. When younger, showered a little less frequently with it typically being every other day.

Another student wrote:

> Shower when I wake up
> Shower after the gym if I go that day
> If I get sweaty at work I’ll shower when I get home
> Some days I work 3 shifts in a row, so I shower between shifts

Students were invited to share their responses. The short conversation that resulted drew their attention how even people with as many things in common as students at the same university could put their water heaters to use in very different ways. With this short activity, we laid the groundwork for further thinking about the variety of needs related to water heaters that people could have.

In the next stages of the activity, the 24 students in class were divided into 7 teams of 3-4 students. They were stationed around the room, where large pieces of paper were vertically hung on the walls. Each team was given markers and a pad of sticky notes.

Students were led through an activity that involved an exhaustive brainstorming series, modified from an “Implosion” activity developed by anthropologist Joseph Dumit [15]. This involved consideration of five different topics including “Technical, Economic, Environmental, Social, and Body”. Each topic name was chosen to relate to literature in the social sciences. Students were asked to brainstorm ideas about potential design considerations for the solar water heater for the DR that they had begun calculations about in their pre-class homework. They were given three minutes to focus on each topic and brainstorm responses to questions associated with it. The order in which these topics were presented was carefully designed by the instructors to appropriately scaffold the learning experience based on level of comfort and experience that we thought they might have with the following issues (i.e. we thought that engineering students would be the most comfortable with technical aspects so started there):

1. Technical: What materials might be involved in production and maintenance of DR solar water heaters and integrated components like pipes, thermosiphons, and spigots? Where might these materials come from?
2. Economic: How might solar water heaters be involved in a marketplace in the DR? Who could pay for components? Who would pay for them to be built or maintained?
3. Environmental: How could the environment affect building and maintaining solar heaters in the DR? How could the environment affect how and when people use them for their showers?
4. Social: Who might use solar water heaters in the DR? Who might build solar water heaters? Who might maintain them? Where could people use heaters to take showers? Do people use heated showers around certain activities? What do heated showers mean to people?
5. Body: What kinds of bodies are solar water heaters designed to be built and maintained by? How could age or ability constrain who uses showers and solar heaters in the DR? How could race, class, or gender impact showering?

The facilitators defined the scope of each of these topics, encouraged students, and kept time. After each round, students documented the number of brainstormed ideas on a team worksheet (see Appendix).

3. Post-Class Memo: Reflections on Contexts

The third and final portion of the Social Relevance and Global Context Module invited students to complete a professional engineering memo following their experiences in this class. In this memo, students were asked to present their quantitative solution to the homework problem that they had begun before class regarding this solar water heater, as well as reflections on contextual issues that could have consequences for design considerations for a solar water heater in the DR. This memo assignment was optional for the students and counted as one homework assignment.

In a one-page typed memo, they were asked to:

1. Summarize design results including final calculation regarding problem (including the pipe length that they arrived at and the method they used to determine it).

2. Describe three additional considerations that might be especially important for a solar water heater, and might make the ways that these solar water heaters are designed for use in the DR different than solar water heaters designed for other people in other places.

They were given additional directions that, for each of their three considerations, they should explain:
1. What the consideration is specifically,
2. How the heater design could change if heaters were being built for different places, and
3. Their reasoning in complete English sentences.

They were also invited to submit an additional extra credit exercise where they explored further application of heat transfer principles. Students were reminded of a former student who had successful developed the solar heater and published her results [14]. They were asked if they were to follow her example and try to apply what they had learned from this class to solving a real problem in the world:
1. What concepts from this class would you use?
2. What do you think you would do?
3. What do you think the first step to making that happen would be?

This memo was to be submitted with handwritten calculations at the time of the final exam.

Data Evaluation
Student submissions (worksheets from the in-class activities and memos) were gathered for further analysis. Drs. Przestrzelski and Reddy analyzed themes and robustness of student responses individually and conferred to decide on final coding to establish inter-rater reliability.

Results

Students' Engagement with Pre-Class Homework and Technical Calculation
In response to the Social Relevance and Global Context Module prompt, students outlined their quantitative solutions to the technical word problem that was posed to them. These solutions can be categorized as correct (pipe length of 55 meters) and incorrect (anything other than a pipe length of 55 meters, most commonly 85 meters); indeed, of the 11 memos submitted, 7 (reflecting the work of 8 students) answered the technical word problem correctly. For the four memos that presented an incorrect final answer, all had calculated the correct area but made mistakes when converting the area into the appropriate length. This was essentially an equation conversion error rather than a conceptual error. This quantitative accuracy was mapped to student success in the class at large and will be later discussed.

This data, coupled with the final course grades of the 14 students who participated in writing memos, which include 12 higher grades (A or A-) and 2 lower grades (C+), can help us understand how participants were engaging with the material of the course overall and those aspects of the module that related to a technically focused problem. In this course overall, 54% (15/28) of the students earned grades in the A range, 32% (9/28) earned grades in the B range, and 14% (4/28) earned grades in the C range. Students who turned in memos were at the top and bottom of the class.

Students' Engagement with In-Class Activity: Designing Beyond Ourselves

In the in-class activity, after students reflected individually on their own showering practices, they were asked to brainstorm potential design considerations with the goal to model some topics that could be later included in the post-class reflection/memo. Before starting the rounds for brainstorming, one student asked what population in the DR he should be thinking about. The facilitators had not known this, but he told the class that he had family in the DR—and that, while most people might consider the DR to be a site of poverty, his family members were quite wealthy and lived in a private compound. While he was only asking for clarification, his question was important to the activity for three reasons. First, it drew the class's attention to the potential diversity of experience in the DR, and challenged assumptions that they might have had that people there were poor or lived modestly. Second, it provided the opportunity for at least one student to make an important connection. Student learning is supported when they can make connections between lessons in the classroom and other aspects of their experiences [16]. Third, this student's question allowed us to encourage the kind of speculation that we wanted students to engage in during the in-class activity. What did we know about how these water heaters could be used in the DR, anyway? Overall, this student's question demonstrates the importance of allowing students to participate in the conversations that frame this in-class activity and bring their whole selves and experiences into class. With this student's question, we had an unexpected and welcome teaching opportunity.

During the brainstorming, students were pushed for quantity over quality of ideas and to discourage judgment to enhance the creativity in the room. For this reason, while there were many ideas generated and the quality of these ideas was not assessed.

While some teams generated more ideas about contextual issues than others, all teams had success for each round. The brainstormed idea totals were compiled and averaged by team and by round, as shown in Table 1.

Table 1. Student brainstorming teams and idea totals.

	Round 1-Technical	*Round 2-Economic*	*Round 3-Environmental*	*Round 4-Social*	*Round 5-Body*	**TOTAL BY TEAM**	**AVERAGE WITHIN TEAM**
Team A	10	5	9	13	8	45	9
Team B	7	7	6	11	5	36	7.2
Team C	17	20	12	17	11	77	15.4
Team D	13	13	9	12	12	59	11.8
Team E	8	13	14	7	13	55	11
Team F	7	9	12	12	8	48	9.6
Team G	4	5	10	10	4	33	6.6
TOTAL BY ROUND	66	72	72	82	61		
AVERAGE BY ROUND	9.43	10.29	10.29	11.71	8.71		

Teams ranged in total ideas about contextual issues from a low of 33 (Team G) to a high of 77 (Team C). While certain teams did have four teammates (Team A, D, and G), there is no direct correlation between team member and total number of ideas. It is interesting to note that teams with three members were able to generate the same number of ideas as those teams with four members. The average ideas per round ranged from just above 8 to nearly 12 ideas, with the most ideas being generated during Round 4 (Social) and the least during Round 5 (Body). These ideas were compared to responses in the student memos following class to evaluate trends in student attention to contextual issues.

Students' Engagement with Post-Class Memo: Reflections on Contexts

1. *Chosen Areas of Context*

We received 11 memos and 7 additional extra credit materials from a total of 14 students to analyze. Students could choose to submit the memo as individuals or in small teams. All 11 memos addressed three major ideas about context and implications for design, making a total of 33 ideas to be coded. Each idea was coded as one of the five context areas given in the in-class activity described detail above (Technical, Economic, Environmental, Social, or Body). The total distribution of these codes can be seen in Table 2. The ideas about context that students chose to reflect on were predominantly (52%) environmental. These included reflections like:

> In the United States a person does not consider bacteria entering the water they bathe in, but this could be something that occurs in other places around the world. Water can get contaminated if it is left still and exposed for too long a period of time…Raising the temperature 12 degrees Celsius could kill some but not all bacteria. Because of this the tank could be designed to heat up well past the 12 degree temperature spike for some time to kill even more bacteria.

Students also explored ideas about social context. These reflections, which were 24% of student responses, highlighted issues such as:

> Being poor or living in a rural area does not disqualify someone from having an aesthetic preference. The water heater can be bulky and unsightly if installed with merely practical considerations. It would be good to work with each client to find a solution for the most pleasing way to incorporate the heater.

Table 2. Themes in ideas about contextual issues with implications for design from student memos coded by the five context areas from the in-class activity.

	Frequency in Responses [#]	Percentage of Responses [%]
Environmental	17	52%
Social	8	24%
Technical	3	9%
Economic	3	9%
Body	2	6%

Students also considered issues that could be considered technical, economic, and related to individual bodies, but to a lesser extent. Issues categorized as technical included:

> Some locations might not have access to certain materials such as pvc. This would make it very difficult and costly to not only importing the material but having extra incase a pipe breaks.

Issues that we categorized as economic included:

> …a water heater must be a reasonable investment for the customers…If a family that is already experiencing poverty is considering purchasing one of these relatively cheap water heaters they must gain enough benefit in water temperature.

Issues related to embodiment included:

> Consider how the people actually shower i.e. Let the water run during the whole duration of the shower or if they let the water wet them then turn it off soap up then rinse off.

Each memo contained three context issues that students felt were worth investigating. The prioritization of these context areas might be further explored with student focus groups or guided reflections in future iterations of this module. Findings might not only lend themselves to a clearer understanding of why the distribution was skewed towards "Environmental" versus "Body", but might support further module design decisions.

2. Depth of Context

All students were given credit for their responses in their course grade. To evaluate the memos, we sorted them into two categories to reflect their comparative depth. Of the 11 memos we received from 14 students, we found that 7 (the work of 8 students) were robust and treated these context pieces in depth. Our criteria for assessing this included:

- Sophistication of their response (For example, a response that suggested that the DR, as a whole, may not have hardware stores at all might be considered unsophisticated, while a response that considered that individual aesthetic taste might differ was sophisticated).
- Extensive reflection in their response (For example, a single sentence indicated less extensive reflection, while those that offered several sentences could be considered to have reflected more substantially).
- Degree to which they followed the prompt (For example, those that explained how the issues they brought up might have consequences for design were considered to have followed the prompt more closely, and those that only listed ideas about contextual issues without reflecting on potential implications for design were considered to have followed the prompt less closely).

One example of a memo consideration considered "more in-depth" is as follows:

> One of the additional considerations that I believe is especially important for a solar water heater would be the ability of the components to withstand the elements present in an outdoor environment. This would be accomplished by ensuring the materials used to construct the heater are highly durable and the location of the heater mount is very sturdy. In our context of the Dominican Republic, the heater must withstand possible extreme tropical storms, earthquakes, flooding, etc… All these situations could result in the

structure that holds the tank collapsing and possibly injuring people below. Therefore, design considerations such as placing the system on an inclined hill or creating a separate structure for the tank might be necessary. This may change in other locations around the world such as in places which the infrastructure has been designed for natural disasters such as earthquakes (California) or in a location in which these issues are less of an issue such as in a high mountain or desert location (Colorado, Arizona).

The students whose considerations were identified as “less in-depth” did not seem to engage with or have a proper handling of the larger context. One example of a memo consideration considered “less in-depth” is:

> Our first design consideration would be the weather of where the water heater is located. Will inclimate [sic] weather corrode the pvc pipe?

3. *Assessing Student Work on Context Issues, Quantitative Calculation, Reflection on Course Topic, and Course Performance Overall*

When students responses to the context piece are considered with respect to their responses to the technical problem framed for them and to their performance in the course overall, a few trends emerge (see Table 3).

Table 3. Overview of students’ memo depth, quantitative calculations, extra credit, and overall grade in the Heat Transfer course, coded 1 for high and 0 for low in all categories.

Memo #	Student ID Code	Memo Depth (1 or 0)	Quantitative Calculation: correct or incorrect (1 or 0)	Extra Credit: Larger Connection to Course (1 or 0)	Semester Grade (1 or 0)
2	A	1	1	0	1
4	B	1	0	0	0
5	C	1	0	0	0
6	D	1	1	0	1
8	E	1	1	0	1
9	F	1	0	1	1
10	G	1	1	1	1
11	H	1	1	1	1
3	J	0	1	0	1
1	I	0	1	1	1
1	N	0	1	1	1
7	K	0	0	0	1
7	L	0	0	0	1
7	M	0	0	0	1

Of the 8 memos that demonstrate depth in their engagement with contextual issues (all of which were authored by individual students), only 5 have the quantitative problem solved correctly, and only 3 used the extra credit assignment to demonstrate engagement with course content. Only 5 are receiving a high grade in the course as a whole.

The instructor of record for the class evaluated the seven submitted extra credit responses and indicated that 4 of the responses (that is, the work of 5 students) showed serious engagement with course concepts. Of these four memos, all presented the correct quantitative solution, but only three considered context with serious depth. It is notable that in a class in which most students received a final grade in the A range (15/28) or the B range (9/28), two students who were receiving C+ grades, among the lowest grades in the class, were able to produce deep considerations of context although their memos may not have displayed a grasp of the necessary equations and or of the further application of course content in extra credit.

Discussion

Overall, the collective results of this implementation of the Social Relevance and Global Context show that students in a heat transfer class were able to engage with considerations of heat transfer content beyond the technical. While the module relates to Heat Transfer content, it was not tightly integrated into the rest of the course. This may be reflected in the fact that depth of attention to context issues in student memos is related to neither success with other parts of the assignment, nor in the class in general. Future work might integrate context issues into learning objectives of this course. This would make this module better integrated with the rest of the course and may help students who are not otherwise achieving high marks in the class engage with the material.

Different students may become engaged in a class in different ways. Engagement can be crucial to participation and success in the classroom and course of study [4]. The way that students who had low grades in the course were able to engage with this module is interesting, and suggests the potential utility of engaging student attention in different ways. This module could provide opportunities for students who are having trouble with course material to engage with it in new ways and to find paths toward success—but, as there are only two individuals represented here, there is a limit to the kinds of wider conclusions it is reasonable to draw.

Results from the in-class brainstorming exercise suggest that students are ready to think about context in many ways. Fewer context issues related to bodies were brainstormed in the in-class activity or developed in out-of-class assignments than others, which suggests that this may be a more challenging theme for students. The majority of context issues that students developed in their memos relate to environment. This presents both an opportunity and a challenge. It suggests that these students are ready to think about the environmental context of their work, and that further iterations of this module might build on this demonstrated interest. It also suggests that students might benefit from further support to think about other kinds of context, particularly as economic, social, and body context issues can all be crucial to design considerations in engineering. It might be beneficial for faculty who use this module to spend more time during class reflecting on the brainstormed ideas of each round, challenging the assumptions in large class debriefs. We were fortunate to have an interdisciplinary research team. Engineering faculty might consider reaching out to colleagues in disciplines such as Anthropology, Sociology, or Ethnic Studies for help in facilitation or discussions of larger context.

This first implementation had some logistical challenges. This module was integrated into the course late in the semester, and therefore the weight of the project was equivalent to only one homework assignment. The in-class activities occurred in the final week of classes, a week before the final exam. This did not allow much time for student reflection and meant that preparing the memo might be seen as conflicting with studying for the final exam. In the future, this module will be included on the syllabus, integrated earlier in the semester, and assigned a percentage of the final course grade. Students were given the option to submit a memo as an optional assignment due to late integration into the course—most of those who submitted were already receiving high semester grades. In the future, the memo assignment will be mandatory for all students. The students were invited to work in teams or individually to complete the memo. In future iterations of the module, students will not be given the option, but rather the instructors will decide when the memo is assigned. Given that there are advantages and disadvantages to both individual and small group memos, this is a decision for the instructor.

Future efforts might be studied, not just through summative evaluation, but with attention to student engagement with the ABET 2000 student outcome h that students have "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context." This might be best explored through short reflection assignments. The instructor of record could assign a number of assignments throughout the course, asking students to reflect on context issues. Students could be awarded points for completion, but we, as a research team, could review and analyze them to help us understand how the students are thinking about context issues or why they are attracted to environmental issues rather than issues around bodies.

Conclusion

The University of San Diego's commitment to Changemaking is not distinct from its pursuit of academic excellence; nor, for all the challenges that they may pose, should ABET requirements of "broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context" be considered disengaged from the technical skills necessary for successful engineers. The Social Relevance and Global Context implemented in this technically focused Heat Transfer course provide initial work to integrate the technical with the social in the classroom and can be seen as a working model for others seeking to help educate more effective engineering graduates ready to design solutions from a sociotechnical perspective.

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Appendix: Facilitator Guide and Student Worksheets

Implosion

Developed from "Implosion Project" activity
(Designed by Joe Dumit, UC Davis)

"Implosion Projects are attempts to teach and learn about the embeddedness of objects, facts, actions, people in the world and the world in them. While brainstorming, you hopefully find ways to exhaust your stories about what is interesting about your implosion and come to see their limitations, as new patterns, relations, and actors come to mind…. The implosion process is designed to daunt and to lure. If you already know your story, then you will do no more than repeat common sense. Ideally the process will reveal connections that you did not know and that you did not know you cared about."-

Dumit, Joseph. "Writing the Implosion: Teaching the World One Thing at a Time." *Cultural Anthropology* 29, no. 2 (2014): 344–362.

What's involved in a shower?

Technical dimensions: What materials might be involved in production and maintenance of DR solar water heaters and integrated components like pipes, thermo-syphons, and spigots? Where might these materials come from?

Economic dimensions: How might solar water heaters be involved in a marketplace in the DR? Who could pay for components? Who would pay for them to be built or maintained?

Environmental dimensions: How could the environment affect building and maintaining solar heaters in the DR? How could the environment affect how and when people use them for their showers?

Social dimensions: Who might use solar water heaters in the DR? Who might build solar water heaters? Who might maintain them? Where could people use heaters to take showers? Do people use heated showers around certain activities? What do heated showers mean to people?

Body dimensions: What kinds of bodies are solar water heaters designed to be built maintained by? How could age or ability constrain who uses showers and solar heaters in the DR? How could race, class, or gender impact showering?

Designing Beyond Ourselves
MENG XXX
[DATE]

Appropriate design consideration is essential in many fields, especially engineering. Today, your design team will identify design criteria associated with the task you have been assigned—to design a solar thermal water heater for the Dominican Republic.

Team member names:

_______________________________________ _______________________________________
_______________________________________ _______________________________________
_______________________________________ _______________________________________

STEP ONE

You and your team will consider design criteria (without jumping into the solution space quite yet) from a different perspective each round. Be sure to think beyond your first design considerations… if you don't, your solution that follows might not solve the (right) problem.

Our team brainstormed this many design criteria for:

Round 1	Round 2	Round 3	Round 4	Round 5

STEP TWO

Two of our most surprising brainstormed design criteria are:

- ____
- ____

These are our two most surprising brainstormed design criteria because:

- ____
  ____
- ____
  ____

Due Monday December 18, 2017 at 5 pm

MENG XXX- Heat Transfer Final Project Memo

After the activity we did in class on December 13, you should have some ideas about how a solar water heater might relate to its *context*, or the complex technical, environmental, and social world around it.

In this one-page typed memo, please **summarize** your design results including your final pipe length and the method you used to determine it. You submit handwritten calculations to back up this design. In addition, please describe **three additional considerations** that you think are especially important for a solar water heater, and might make the ways that these solar water heaters are designed for use in the Dominican Republic different than solar water heaters designed for other people in other places. These three additional considerations should *not* be the specifications that [Author] gave you when describing the solar water heater problem, but they should be considerations that you think could have consequences for solar heater design.

For each of your **three considerations**, please explain **1) what the consideration is specifically** and **2) how the heater design could change if heaters were being built for different places.** Describe your reasoning in complete English sentences.

For example (do not use this one and yours might have more detail about impact on design) : One consideration might be whether people keep bears as pets in this culture. Bears need to be washed regularly and have powerful jaws. They might chew on shower spigots, and so pipes and shower spigots should be made of stronger materials than PVC if this is the case. This could increase the cost of the design.

Extra Credit
If you were to follow in [Former student]'s footsteps and try to apply what you've learned from this class to solving a real problem in the world,
1) what concepts from this class would you use?
2) what do you think you would do?
3) what do you think the first step to making that happen would be?

Designing Beyond Ourselves

8-8:55AM (55 minutes)

Timeline of Module Two

Pre-Dec 13th	Dec 13th	Dec 18th
Work on preliminary calculations with handwritten support	In-class activity Assign memo	1-page memo due

(!!!!!!) DRAFT INFORMED CONSENT (to be emailed before class/signed in class)

Tic Toc of Dec 13th Class

Time	Activity	Facilitator Notes
8:00-8:03AM	Introduction	Why are we here today? You've been assigned a task- design a solar thermal water heater for the Dominican Republic. We are experts in social science and design thinking here to think bigger about the problem you've been tasked with as an engineer. This heater you've been asked to design has been designed with a goal to "provide a 5-minute shower at a flow rate of 1.2 gallons per mission for a household size of five". Share with a partner the “L” that you have calculated thus far. Engineering is an extremely technical field- it has to be because there is a lot that depends on the solutions we make. But there’s more that we have to be ready to consider as engineers.. You have been tasked with designing a water heater for the Dominican Republic, a place very different from here. The project thus far has been very highly specified, but for your design to succeed, you must consider more than just the technical piece of the project. While we are designing for the D.R., let's first have a look at the shower experiences we know the best. Ours.
8:03-8:05AM	Activity I: Break down your individual shower experience	To be completed INDIVIDUALLY. Put on classical thinking music (if possible in classroom). A worksheet and a facilitator stating some of the prompts below guides them through analysis of their own shower experience Consider: duration of your shower, particular days that you shower, how shower experiences change with age, type of shower (temperature, water pressure, showerhead, closed versus open

		shower, overhead fan on off, etc.).
8:05-8:10AM	Discussion about our own shower experiences	Ask students to contribute to larger discussion around shower preferences in the U.S. Ask them to consider: duration of your shower, particular days that you shower, how shower experiences change with age, type of shower (temperature, water pressure, showerhead, closed versus open shower, overhead fan on off, etc.). Ask: Have you ever had an argument because of a shower -- think roommate, old houses, planning out showers (nighttime vs morning showers)? Ask: Has there ever been a time where your shower routine changed from that which you've described on your worksheet? (Give examples)
8:10-8:15AM	Transition to the Brainstorm	Mini debrief tying the previous activity to the later brain dump ++frame: in engineering classes you often get very specific specifications regarding the scope of your work. When you go into professional practice you might not, or you might be integrated into a team. There, you don't have to be responsible for everything-- you are an engineering expert, after all-- but part of being a good team member is asking good questions. Short introduction to brainstorming (good vs bad demo) Get in teams of 4 Locate a brainstorming studio (butcher paper on walls around the room) and get post-its/sharpies for EVERYONE in your team
8:15-8:35	Activity II: Structured Brainstorming With implosion activity guide and worksheet	5 rounds of 3 minutes to brainstorm various tasked implications (ex: technical, material, environmental, social, bodily from Beth's Implosion exercise) Pass out worksheet to document quantity of post-its for each round (Go for quantity not quality) We are going to ask you to evaluate the D.R. shower experience from different dimensions/perspectives. On the screen, you will see some prompting questions in different areas. These questions should get you thinking about things to consider for your D.R. shower-- as those thoughts come up, jot them down and put them on the wall. These thoughts can be questions you have, design concerns, things you maybe should look into more (if you were implementing this in the D.R.)... Questions? The first we want you to consider is Technical. GO. R1: Technical R2: Economic R3: Environmental R4: Social R5: Body In final minutes, ask students to consider which two were most surprising to them and why (Document on the worksheet)

<table>
<tr><td>8:35-8:50</td><td>Debrief of the activity
+
Reflection on the Underlying Assumptions</td><td>Reflect on
I: Trends in the brainstorming-- what do we know?
II: Gaps identified by brainstorming -- what don't we know?

Reflect on Activity I vs Activity II:
→ What was important to me (my shower experience) vs what is important to others (users but also, others who might be helping design this shower (design teams)
→ What might be true of us that might not be true for others?
→ What might be true of the users that we didn't consider?
• Who's going to use this shower? One family or multiple individuals/families sharing?
• When/where will a shower be used? (Ex: Beth showering at gym when roommate's cat kept peeing in the apartment shower)
• Priorities for consumption in D.R.?
• Financial affordances in D.R. ($200 for the system you've designed-- is that accessible?!, RASCA, $200 once better than a recurring cost for pump/maintenance? or better than none?
• What is 12 degrees C above room temperature? Is there a desire for a hotter shower at all?
• What is the average temp in D.R.? (Ex: Beth only taking cold showers in Nicaragua bc it was so hot outside)

Thinking beyond ourselves
→ What societal assumptions did you make regarding the culture that this thermal water heating system would be implemented in?
→ How might implementation of this system differ when taking into account variable economies, government policies, cultures, etc. in different regions of the world?
→ Which of these might you have considered (or will consider in the future) when designing these solutions as socially-minded engineers?</td></tr>
<tr><td>8:50-8:55AM</td><td>Assign memo with memo assignment</td><td>Engineering projects in the real world don't stop at a calculation. Written reports are often generated to connect calculations to more meaningful considerations. You will be doing that for one final portion of this project. Having thought through some engineering assumptions regarding your project, the final piece of your project is to write a 1-page memo reflecting on some of the considerations discussed today.

Pass out the memo assignment.</td></tr>
<tr><td>8:55AM</td><td>Clean up/Fin</td><td>Take the large post-it notes with us. Collect the IL/IW feedback from the front of the room.</td></tr>
</table>

Space Set-up

Prior to class, the early-arriving students will assist the teaching team in moving the tables and chairs giving space for standing space along the walls.

Artifacts

"Break down your shower experience" reflections

Worksheet that compiles considerations

… and, soon, a memo assignment

Materials

- Post-it notes
- Sharpies
- Large wall post-its