Creating Space for Sociotechnical Thinking in Engineering Education

Facilitators:
Kathryn Johnson, Colorado School of Mines
Barbara Moskal, Texas Tech University
1. Introduction
Who We Are: Research Team

• Faculty
  • Katie Johnson (CSM, PI)
  • Jenifer Blacklock (CSM)
  • Stephanie Claussen (CSM)
  • Jon Leydens (CSM)
  • Barb Moskal (TTU)
  • Janet Tsai (CU)

• Students
  • Alyssa Boll (Graduated)
  • Olivia Cordova (Graduated)
  • Brandon Dickerson (Senior, EE)
  • Jackie (Walter) Erickson (Senior, EE)
  • Colin Endsley (Junior, ME)
Target Student Population

University of Colorado Boulder (CU)
- 36,000-student state university with many majors
- B.S., M.S., and Ph.D. in engineering
- 1 class: 1st year introduction to engineering projects

Colorado School of Mines (CSM)
- 6300-student state university focused on STEM majors
- B.S., M.S., and Ph.D. in engineering
- 2 classes: 2nd year introduction to mechanical engineering, 3rd year electromagnetics
Acknowledgement

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Motivation: Prioritization of the Technical

False
- The sociotechnical divide of U.S. engineering education

Engineering education is often depoliticized and decontextualized and prioritizes technical work over all else

- Poor pedagogy
- Misrepresentation of engineering practice
Motivation: The Bridge of Engineering Practice

- Despite knowing for decades about the Knowledge-Practice Gap between engineering education and practice, we do not have clear, effective models or best practices for teaching sociotechnical thinking.

Bruce Seely, “The Other Re-engineering of Engineering Education, 1900–1965” (JEE, 1999)
Interjection: What Do We Mean by “Social”?  

• Our team’s definition of social is inclusive of environmental, ethical, economic, health, safety, political, and cultural factors.  

• Students may have more narrow definitions; for example, referring only to the social license to operate. Or completely different ones, such as socialization skills (from a FG).

Operative Questions: How does the project outcome or problem solution affect all stakeholders? Does the outcome or solution involve any increase or decrease in access to services in education, transportation, public health, etc.? From the solution, who benefits and who suffers?
Sociotechnical Thinking

• “The interplay between relevant social and technical factors in the problem definition and solution process.”
Sociotechnical Continuum

Social-technical dualism

Social-technical integration

High Relevance, "Real" EG

Low Relevance to Irrelevant

Technical Dimensions

Social Dimensions
Sociotechnical Habits of Mind

1. Knowledge Strengths and Limitations
   
   To what degree do students identify and use both technical and non-technical bodies of knowledge to inform engineering decision making?

2. Diverse Knowledge and Perspectives
   
   To what degree do engineering students demonstrate understanding of the importance of learning to work with people who define problems differently?

3. Knowledge and Expertise Plurality
   
   To what degree do engineering students render visible and legitimize “the human dimensions of engineering work alongside technical problem solving?”

Goals for This Session

1. Introduction

2. Participant background
   We want to learn about you and your interests in this topic. What are you hoping to get out of the next hour?

3. Relevant research
   What we are doing that’s relevant to your interests?

4. Group feedback
   What can we learn from you?

5. Brainstorming
   Time for you to reflect: what will you do next?

6. Paths forward
   How can we all help each other?
2. Participant Background
Participant Background

• In small groups, identify a scribe and recorder, then discuss:
  1. What do you know about sociotechnical thinking?
  2. Have you integrated sociotechnical thinking in your engineering classes? If so, how?
  3. Are you aware of others integrating sociotechnical thinking and engineering in your university’s engineering programs?

• Report back to the larger group
  4. What challenges, opportunities, and/or breakthroughs have you encountered?
3. Relevant Research
**Relevant Research Overview**

**Struggles**
- Finding time in an already content-intensive course
- Most of us were taught in a dichotomized fashion with technical separated from social; we are navigating uncharted waters
- The overall curriculum is at odds with our goals

**Breakthroughs**
- Problem (re-)definition
- Our Interview Assignment: an attempt to accentuate how the social and technical dimensions of engineering problems intersect
- Making the curriculum visible
Relevant Research Elements

• Key elements of our work to date:
  I. Teaching sociotechnical thinking
  II. Data collection
  III. Data analysis
  IV. Potential new research questions and areas
Element I: Teaching Methods and Interventions

• Problem (re-)definitions
• Mini-lectures
• Interview assignment
Teaching 1: Problem Redefinition

Instead of

“Design a water tank to meet these (quantitative) specifications”,

consider

“What water tank performance characteristics do you think would be important to people living in a remote village in an arid climate? Translate these characteristics to quantitative specifications, and design the tank to meet those specifications.”
Basic question
“How do you prevent getting “doored” on a bicycle?”

Possible technical solution
Sensor system that lets drivers know when a bicycle is nearby

Non-technical solution: the “Dutch Reach”
“For decades now in the Netherlands, many drivers have been trained (and tested for their licenses) on a behavior that dramatically reduces the risk of doorings. They do not even have a name for it because it is simply how one opens a car door. Basically, instead of using their door-side (left) arm, they reach over with their other (right) arm.”
Teaching 2: A visible curriculum

• How Socio-Technical is your Major Curriculum?
# Teaching 3: Interview Assignment – Stage 1

- **Stage 1**: Conduct the Interviews, Collect Data, Fill out Worksheet

<table>
<thead>
<tr>
<th>Prompt</th>
<th>Engineer Response</th>
<th>Non-Engineer Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age range (&lt; 18, 18-29, 30-39, 40-49, 50-50, &gt; 60 years old):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relevant Expertise:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1) Why would you solve this problem? What needs does it address?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2) What resources are needed to solve the problem, including people (with specific skills, expertise, and/or experiences) and other resources (money, equipment, facilities etc.)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3) What would a solution look like? What problems might a solution cause?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4) How do you decide if your solution solved the problem?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5) What is missing from the problem? What is uncertain and/or ambiguous?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Teaching 3: Interview Assignment – Stage 2

- Stage 2: Now rewrite the original problem statement and list critical elements of a potential solution based on the information offered by the Engineer vs. the Non-Engineer.

<table>
<thead>
<tr>
<th>Rewritten Problem Statement</th>
<th>With Regards to the Engineer Interview</th>
<th>With Regards to the Non-Engineer Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>List critical elements or important features of a proposed solution to this problem.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Finally, combine both of the rewritten problem statements above to generate a single final problem statement:
- Identify critical elements or important features of a solution to your combined problem statement:
- What from the interviews, your values, and your experiences motivated the ultimate changes from the original to the final problem statement and/or elements of a solution? Comment and explain.
Teaching 3: Interview Assignment – Stage 3 (Student Reflection)

• Assigned roughly 1 week after the Interview Assignments are submitted. Students respond to one or more of the following prompts:

1) What were the main similarities and differences between the responses provided by the engineer and non-engineer?

2) Discuss the degree to which you found it helpful to talk to both the engineer and the non-engineer, and briefly explain why.

3) Knowing what you know now from your two interviewees, would you choose a different engineer or non-engineer to interview if you were to do another round of interviews? Briefly explain your answer.

4) Comments or further discussion about the interviews? Could you envision doing this assignment in another class or your future engineering work?
Element II: Data Collection

• Four primary data sources:
  • Surveys (pre & post) (Qualitative and Quantitative)
  • Focus groups (Qualitative)
  • (Interview) assignments (Primarily Qualitative)
  • Faculty reflection logs (Qualitative)
Data Source 1: Surveys

<table>
<thead>
<tr>
<th>Course</th>
<th>Spring 2018</th>
<th>Fall 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Course 1” - First-year engineering design course (CU)</td>
<td>• Paper survey</td>
<td>• Online survey</td>
</tr>
<tr>
<td></td>
<td>• Week 7</td>
<td>• Week 1</td>
</tr>
<tr>
<td></td>
<td>• n = 21 responses</td>
<td>• n = 329 responses</td>
</tr>
<tr>
<td></td>
<td>• Version 1 (Leydens et al., 2018)</td>
<td>• Version 2 (Q#10 updated)</td>
</tr>
<tr>
<td>“Course 2” - Second-year introduction to mechanical engineering course (CSM)</td>
<td>• Not administered (not yet part of the research)</td>
<td>• Paper survey</td>
</tr>
<tr>
<td></td>
<td>• Week 2</td>
<td>• Week 2</td>
</tr>
<tr>
<td></td>
<td>• n = 148 responses</td>
<td>• n = 148 responses</td>
</tr>
<tr>
<td></td>
<td>• Version 2 (Q#10 updated)</td>
<td>• Version 2 (Q#10 updated)</td>
</tr>
<tr>
<td>“Course 3” - Third-year engineering science course – electromagnetics (CSM)</td>
<td>• Paper survey</td>
<td>• Paper survey</td>
</tr>
<tr>
<td></td>
<td>• Week 7</td>
<td>• Week 5</td>
</tr>
<tr>
<td></td>
<td>• n = 32 responses</td>
<td>• n = 13 responses</td>
</tr>
<tr>
<td></td>
<td>• Version 1</td>
<td>• Version 2 (Q#10 updated)</td>
</tr>
<tr>
<td>Total Responses</td>
<td>• n = 53 responses</td>
<td>• n = 490 responses</td>
</tr>
</tbody>
</table>

• Human subjects research protocols followed at both institutions

Data Source 2: Focus Groups

- Two focus groups per class per semester facilitated by project team members not teaching the classes
- Semi-structured
- 4-6 participants per focus group
- $40 gift card incentive
Data Source 3: (Interview) Assignments

- Student responses collected across all three classes for 1-2 semesters each thus far (ongoing in Fall 2019)
Data Source 4: Faculty Reflection Logs

• Three professors teaching intervention courses maintain weekly reflection logs throughout the semester

• Sample prompts (not mandatory):
  • What do you want your students to understand about sociotechnical thinking this week?
  • How did you balance the competing class requirements within the context of limited class time? When class time was running short, what got dropped?
  • Did thinking about sociotechnical thinking help you to make any “real world” connections?
  • As you assess student learning, how does your assessment mechanism prioritize/deprioritize technical, sociotechnical, and social learning?
  • If students express frustration about sociotechnical elements of class, can you tease out how much frustration is with respect to sociotechnical vs. struggles with more open-ended problem defining and solving in general?
Data Analysis

• Quantitative
  • Surveys (pre & post)

• Qualitative
  • Surveys (pre & post)
  • Focus groups
  • (Interview) assignments
  • Faculty reflection logs
Analysis 1: Survey results (Question 1)

1. Think about your future role as an engineer. For each of the following, rate how important you believe each of these skills will be when you practice engineering as a professional by circling the level of importance that best matches your answer.

- Solve technical problems within familiar contexts
- Apply technical knowledge to novel contexts
- Work with people who define problems differently
- Listen to and integrate the perspectives of both engineers and non-engineers
- Approach problems that are not clearly defined or with uncertain parameters
- Identify project-relevant sociocultural issues
- Follow the rules established by local, national, and institutional authorities
- Work with people having a diverse set of backgrounds
- Acknowledge the strengths and limitations of different forms of knowledge for solving different kinds of problems
### Analysis 1: Survey results: (Question 1 by Gender)

#### Table 3: Q1 Average Scores for Each Skill by Gender

<table>
<thead>
<tr>
<th>Skill</th>
<th>Gender</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solve technical problems within familiar contexts</td>
<td>2.266 Male</td>
<td>0.493</td>
</tr>
<tr>
<td>Apply technical knowledge to novel contexts</td>
<td>2.176 Male</td>
<td>0.453</td>
</tr>
<tr>
<td>Work with people who define problems differently</td>
<td>2.366 Male</td>
<td>0.593</td>
</tr>
<tr>
<td>Listen to and integrate the perspectives of both engineers and non-engineers</td>
<td>2.294 Male</td>
<td>0.00127*</td>
</tr>
<tr>
<td>Approach problems that are not clearly defined or with uncertain parameters</td>
<td>2.252 Male</td>
<td>0.819</td>
</tr>
<tr>
<td>Identify project-relevant sociocultural issues</td>
<td>1.817 Male</td>
<td>0.146</td>
</tr>
<tr>
<td>Follow the rules established by local, national, and institutional authorities</td>
<td>2.366 Male</td>
<td>0.359</td>
</tr>
<tr>
<td>Work with people having a diverse set of backgrounds</td>
<td>2.049 Male</td>
<td>0.0000541*</td>
</tr>
<tr>
<td>Acknowledge the strengths and limitations of different forms of knowledge for solving different kinds of problems</td>
<td>2.217 Male</td>
<td>0.989</td>
</tr>
</tbody>
</table>

* Statistically significant at the $p \leq 0.05$ level.
Analysis 2: Qualitative Analysis Process

2-3 team members code data using NVivo

Codes allowed to emerge from the data

Each writes individual analytic research memo (ARM)

Group meets to discuss and compare interpretations

Consensus ARMs combined for dissemination

Group writes consensus ARM for each semester


“Engineers should always consider social concerns when creating/working on a project, because they are designing a project that should appeal to the masses for marketability.”

“I think while social and non-technical and technical work are all extremely important that an engineer must know what to prioritize at each time.”

“It is an Engineers (sic) responsibility to consider both the technical and non-technical sides, but engineers are and should be trained to solve the technical issues...technical issues should be separated from the nontechnical issues. That way an engineer can focus on what they’re trained for and thus can do they’re (sic) job effectively.”

“Non technical and technical considerations are both important but an engineer should learn more technical solutions.”
Analysis 4: Focus Groups

• Results from Fall 2018 focus group data include two multi-dimensional spectrums:
  • Individual perspective to societal/cultural (inward vs. outward-facing)
  • Dualism to integration
Analysis 5: Faculty Reflection Logs

- Results from Fall 2018 analysis include constructive and interfering elements of the broader curriculum and timing across multiple scales.
New RQ’s 1: Why the differences?

- What factors impact the decline in expected frequency of incorporations of social and environmental considerations into engineering practice from Course 1 (1\textsuperscript{st} year) to Course 3 (3\textsuperscript{rd} year)?
  - Year in school?
  - Major?
  - Gender?
  - Instructor?
  - Other factors?
New RQ’s 2: A messy project!

• Our experience suggests that a team of multiple instructors wrestling with interventions across substantially different classes at different universities may lead to more thoughtful, purposeful sociotechnical integration that may also enable students to more easily apply concepts in multiple classes (not yet shown).
  • What evidence can we collect to prove or disprove these hypotheses?
  • What incentives will support such close collaboration (beyond NSF grants)?
New RQ’s 3: What works?

• Are there particularly promising pedagogical methods that are more successful in promoting sociotechnical thinking or shaping engineering habits of mind across the courses?
New RQ’s 4: The problem definition space

• What goes into—and what remains outside of—the problem definition space and problem frame? Why?
  • Problem definition refers to the key identified variables and metrics in the problem space.
  • Problem frame refers to the broader social context in which the problem is framed.
4. Group Feedback
Feedback

1. What questions do you have about what we have shared today?

2. What suggestions do you have to help us be successful in our research and in promoting sociotechnical thinking among our students?
5. Brainstorming
Individual Brainstorming

1. Think about a class that you teach. How will you create space for students to think sociotechnically within your class?

2. Are there opportunities for you to broaden sociotechnical teaching within your institution beyond classes that you teach?
6. Paths Forward
Paths Forward

• Share a goal from your brainstorming session!

• Given what you’ve heard from us and what we have heard from you, how can we all support each other moving forward?
Thank You!

- Katie Johnson: kjohnson@mines.edu
- Barb Moskal: barb.moskal@ttu.edu

- For more information:
  - http://sociotechnical-education.mines.edu/
  - Leydens and Lucena (2018)