Creating Space for Sociotechnical Thinking in Engineering Education

Facilitators:

Kathryn Johnson, Colorado School of Mines

Barbara Moskal, Texas Tech University

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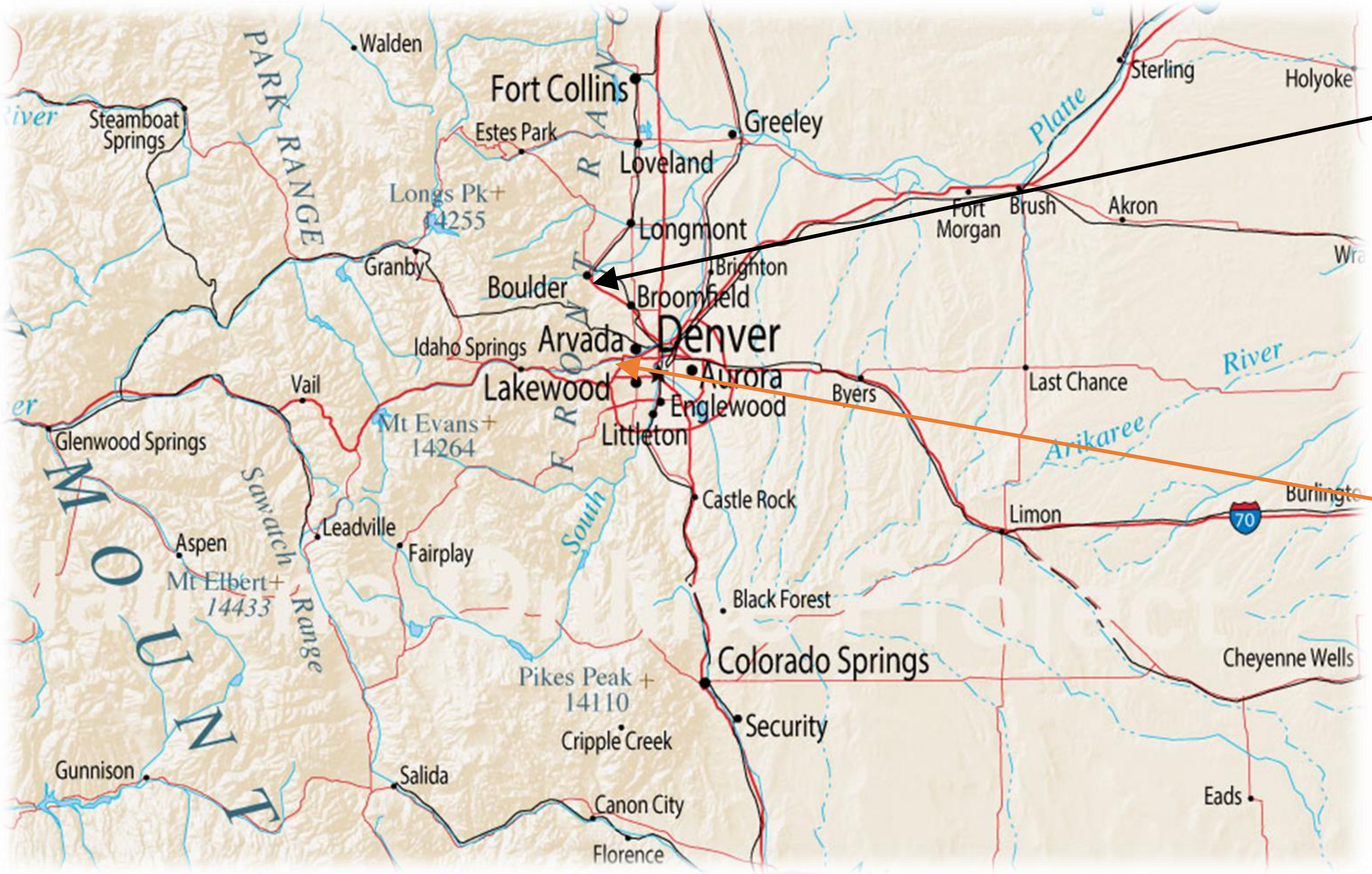
1. Introduction

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

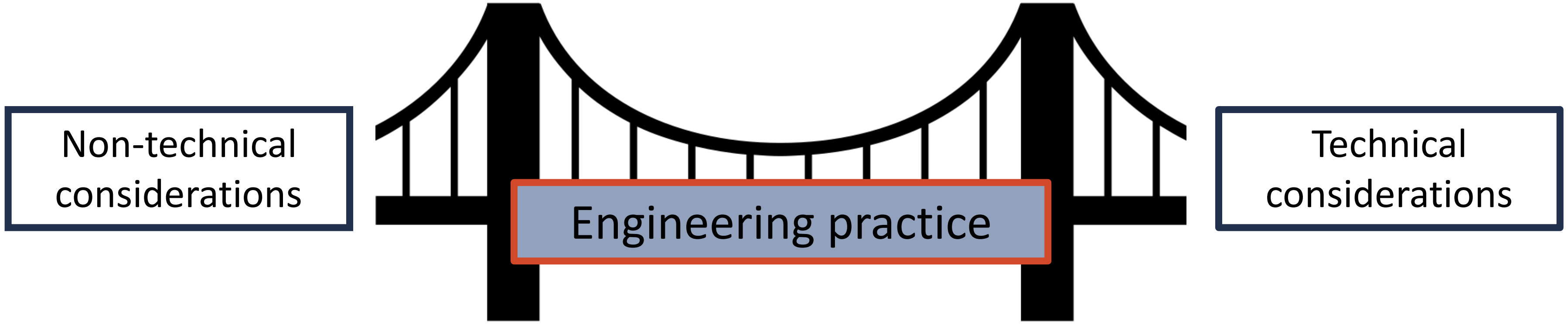
False

- 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)
E. A. Cech, “The (mis)framing of social justice: Why ideologies of depoliticization and meritocracy hinder engineers’ ability to think about social injustices,” in Engineering education for social justice: Critical explorations and opportunities, J. C. Lucena, Ed. Dordrecht; New York: Springer, 2013, pp. 67–84.

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).

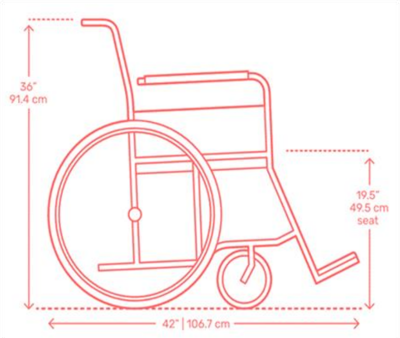
Operative Questions: How does the project outcome or problem solution affect all stakeholders? Does the outcome or solution involve any increase or decrease in access to services in education, transportation, public health, etc.? From the solution, who benefits and who suffers?

Sociotechnical Thinking

- "The interplay between relevant social and technical factors in the problem definition and solution process."

Sociotechnical Continuum

Social-technical dualism ⟷ Sociotechnical integration



High Relevance, "Real" EG

Technical Dimensions

Low Relevance to Irrelevant

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?"

Adapted from Downey, G. (2005). Are engineers losing control of technology?: From 'Problem Solving' to 'Problem Definition and Solution' in engineering education. *Chemical Engineering Research and Design*, 83(6), 583–595. https://doi.org/10.1205/cherd.05095

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

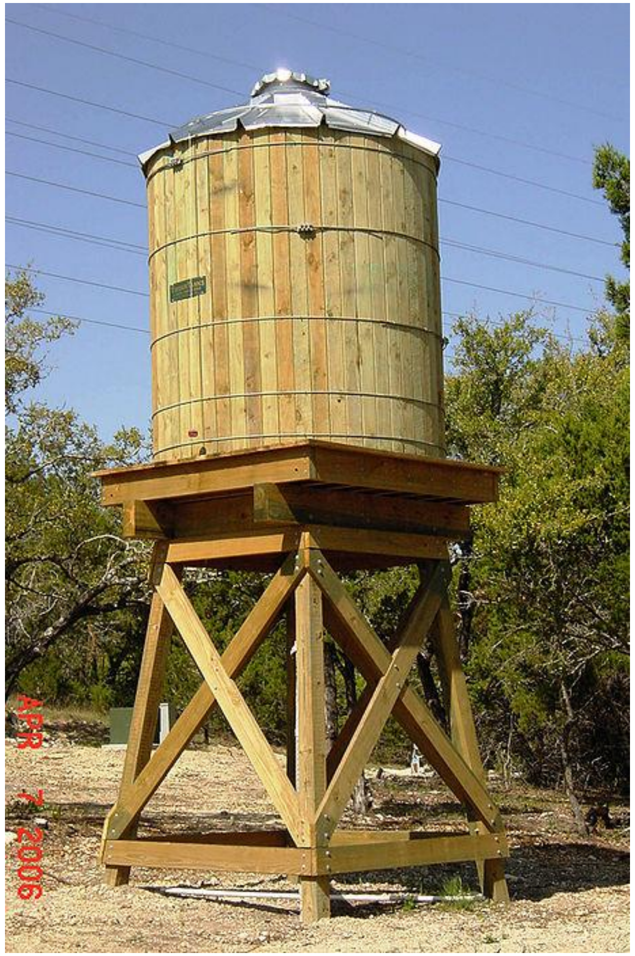
Teaching 1: Problem Redefinition

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."



Teaching 1: Problem Redefinition, continued

Basic question

"How do you prevent getting "doored" on a bicycle?"

Possible technical solution

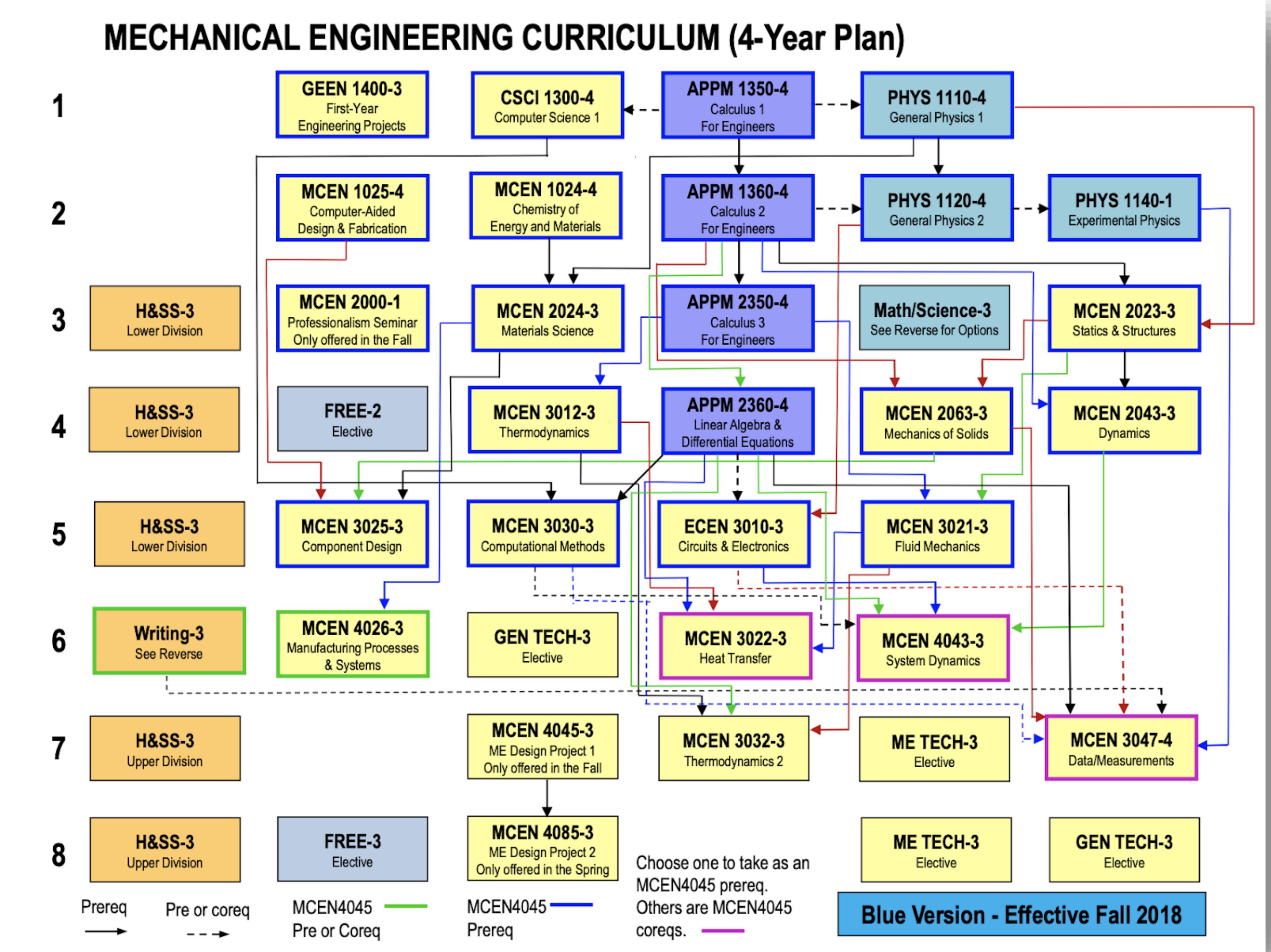
Sensor system that lets drivers know when a bicycle is nearby

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."
https://99percentinvisible.org/article/dutch-reach-clever-workaround-keep-cyclists-getting-doored/

Teaching 2: A visible curriculum

- How Socio-Technical is <u>your</u> Major Curriculum?



Teaching 3: Interview Assignment – Stage 1

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

Prompt	*Engineer Response*	*Non-Engineer Response*
Age range (< 18, 18-29, 30-39, 40-49, 50-50, > 60 years old):		
Gender:		
Relevant Expertise:		
1) Why would you solve this problem? What needs does it address?		
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.)?		
3) What would a solution look like? What problems might a solution cause?		
4) How do you decide if your solution solved the problem?		
5) What is missing from the problem? What is uncertain and/or ambiguous?		

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.

	With Regards to the Engineer Interview	***With Regards to the Non-Engineer Interview***
Rewritten Problem Statement		
List critical elements or important features of a proposed solution to this problem.		

- 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?

Back to Elements I-IV

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

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

- Human subjects research protocols followed at both institutions

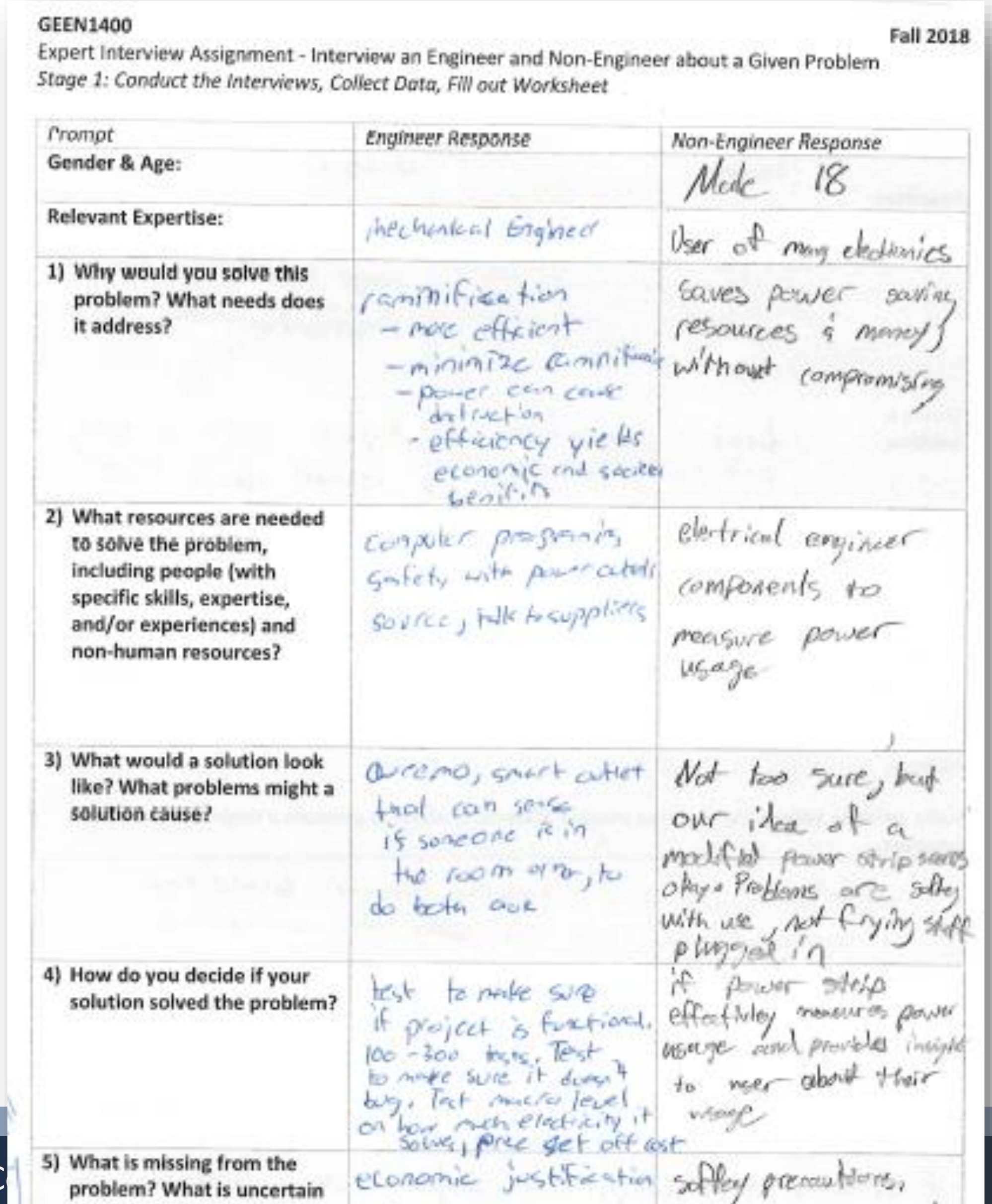
See details inLeydens, J., Johnson, K., Claussen, S., Blacklock, J., Moskal, B., and Cordova, O., "Measuring changes over time in sociotechnical thinking: A survey validation model for sociotechnical habits of mind," Proceedings of the ASEE Annual Conference, Salt Lake City, UT, 2018.

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)



GEEN1400 Fall 2018

Expert Interview Assignment - Interview an Engineer and Non-Engineer about a Given Problem

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

Prompt	Engineer Response	Non-Engineer Response
Gender & Age:		Male 18
Relevant Expertise:	Mechanical Engineer	User of many electronics
1) Why would you solve this problem? What needs does it address?	ramification – more efficient – minimize ramifications – power can cause destruction – efficiency yields economic and societal benefits	Saves power saving resources & money, without compromising
2) What resources are needed to solve the problem, including people (with specific skills, expertise, and/or experiences) and non-human resources?	computer programming, safety with power outlets, source, talk to suppliers	electrical engineer components to measure power usage
3) What would a solution look like? What problems might a solution cause?	Awemo, smart outlet that can sense if someone is in the room or not, to do both out	Not too sure, but our idea of a modified power strip seems okay. Problems are safety with use, not frying stuff plugged in
4) How do you decide if your solution solved the problem?	test to make sure if project is functional. 100-300 tests. Test to make sure it doesn't bug. Test macro level on how much electricity it solves, price set off cost	if power strip effectively measures power usage and provides insight to user about their usage
5) What is missing from the problem? What is uncertain	economic justification	safety precautions,

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?

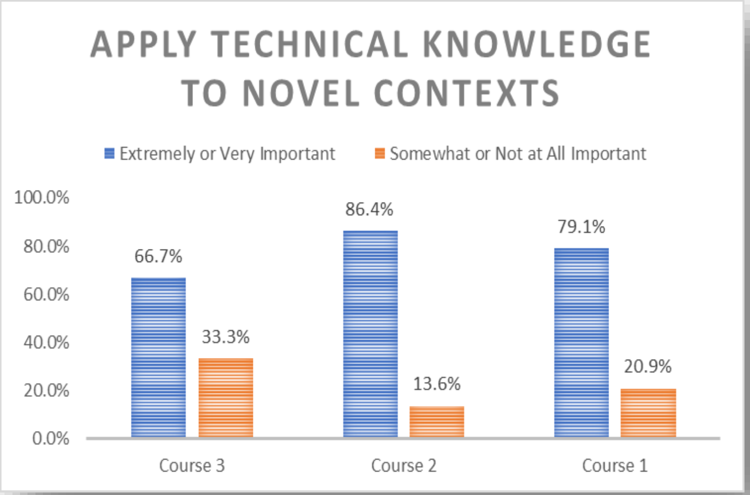
Back to Elements I-IV

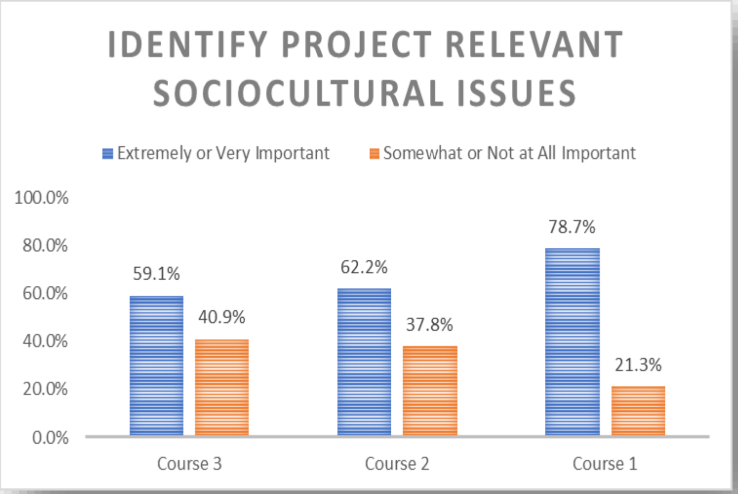
Data Analysis

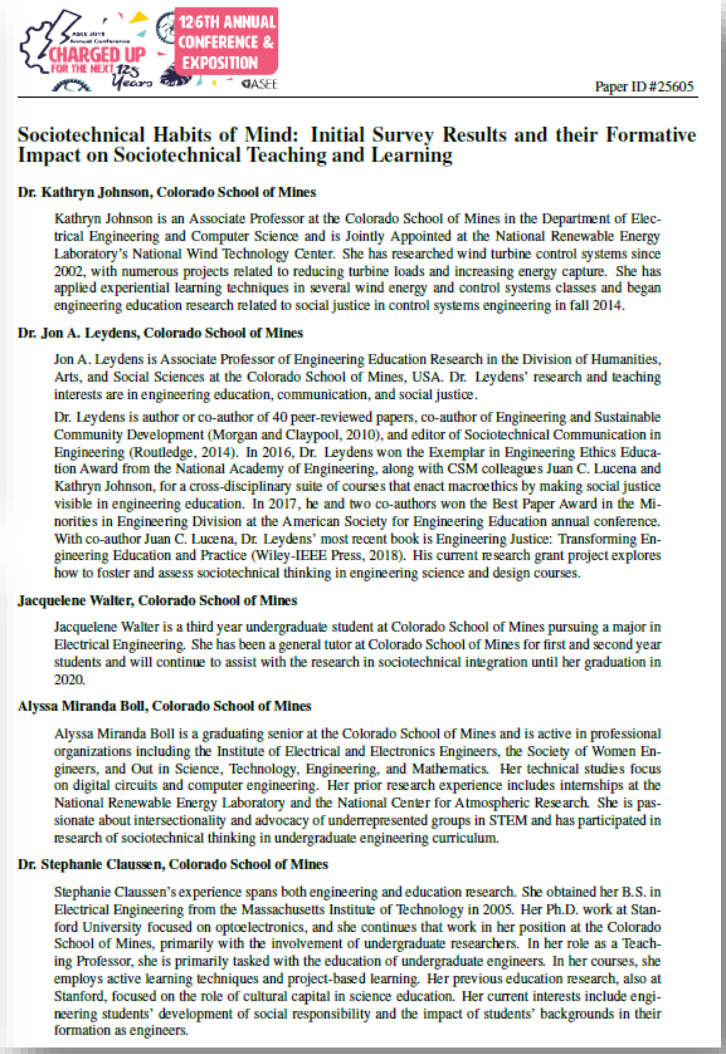
- Quantitative
  - Surveys (pre & post)
- Qualitative
  - Surveys (pre & post)
  - Focus groups
  - (Interview) assignments
  - Faculty reflection logs

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







Paper ID #25605

Sociotechnical Habits of Mind: Initial Survey Results and their Formative Impact on Sociotechnical Teaching and Learning

Dr. Kathryn Johnson, Colorado School of Mines

Kathryn Johnson is an Associate Professor at the Colorado School of Mines in the Department of Electrical Engineering and Computer Science and is Jointly Appointed at the National Renewable Energy Laboratory's National Wind Technology Center. She has researched wind turbine control systems since 2002, with numerous projects related to reducing turbine loads and increasing energy capture. She has applied experiential learning techniques in several wind energy and control systems classes and began engineering education research related to social justice in control systems engineering in fall 2014.

Dr. Jon A. Leydens, Colorado School of Mines

Jon A. Leydens is Associate Professor of Engineering Education Research in the Division of Humanities, Arts, and Social Sciences at the Colorado School of Mines, USA. Dr. Leydens' research and teaching interests are in engineering education, communication, and social justice.

Dr. Leydens is author or co-author of 40 peer-reviewed papers, co-author of Engineering and Sustainable Community Development (Morgan and Claypool, 2010), and editor of Sociotechnical Communication in Engineering (Routledge, 2014). In 2016, Dr. Leydens won the Exemplar in Engineering Ethics Education Award from the National Academy of Engineering, along with CSM colleagues Juan C. Lucena and Kathryn Johnson, for a cross-disciplinary suite of courses that enact macroethics by making social justice visible in engineering education. In 2017, he and two co-authors won the Best Paper Award in the Minorities in Engineering Division at the American Society for Engineering Education annual conference. With co-author Juan C. Lucena, Dr. Leydens' most recent book is Engineering Justice: Transforming Engineering Education and Practice (Wiley-IEEE Press, 2018). His current research grant project explores how to foster and assess sociotechnical thinking in engineering science and design courses.

Jacquelene Walter, Colorado School of Mines

Jacquelene Walter is a third year undergraduate student at Colorado School of Mines pursuing a major in Electrical Engineering. She has been a general tutor at Colorado School of Mines for first and second year students and will continue to assist with the research in sociotechnical integration until her graduation in 2020.

Alyssa Miranda Boll, Colorado School of Mines

Alyssa Miranda Boll is a graduating senior at the Colorado School of Mines and is active in professional organizations including the Institute of Electrical and Electronics Engineers, the Society of Women Engineers, and Out in Science, Technology, Engineering, and Mathematics. Her technical studies focus on digital circuits and computer engineering. Her prior research experience includes internships at the National Renewable Energy Laboratory and the National Center for Atmospheric Research. She is passionate about intersectionality and advocacy of underrepresented groups in STEM and has participated in research of sociotechnical thinking in undergraduate engineering curriculum.

Dr. Stephanie Claussen, Colorado School of Mines

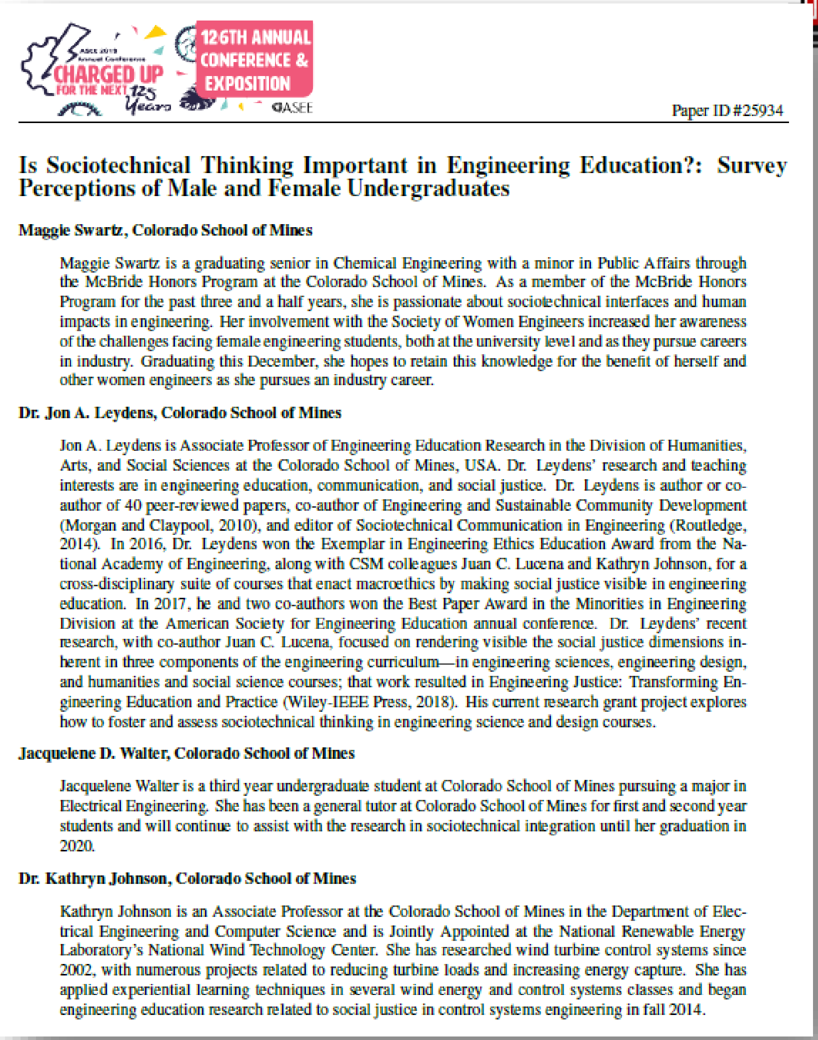
Stephanie Claussen's experience spans both engineering and education research. She obtained her B.S. in Electrical Engineering from the Massachusetts Institute of Technology in 2005. Her Ph.D. work at Stanford University focused on optoelectronics, and she continues that work in her position at the Colorado School of Mines, primarily with the involvement of undergraduate researchers. In her role as a Teaching Professor, she is primarily tasked with the education of undergraduate engineers. In her courses, she employs active learning techniques and project-based learning. Her previous education research, also at Stanford, focused on the role of cultural capital in science education. Her current interests include engineering students' development of social responsibility and the impact of students' backgrounds in their formation as engineers.

Analysis 1: Survey results: (Question 1 by Gender)

Table 3: Q1 Average Scores for Each Skill by Gender

Skill	Gender		P-Value
	Male	Female	
Solve technical problems within familiar contexts	2.266	2.182	0.493
Apply technical knowledge to novel contexts	2.176	2.091	0.453
Work with people who define problems differently	2.366	2.309	0.593
Listen to and integrate the perspectives of both engineers and non-engineers	2.294	2.600	0.00127*
Approach problems that are not clearly defined or with uncertain parameters	2.252	2.278	0.819
Identify project-relevant sociocultural issues	1.817	2.000	0.146
Follow the rules established by local, national, and institutional authorities	2.366	2.259	0.359
Work with people having a diverse set of backgrounds	2.049	2.537	0.0000541*
Acknowledge the strengths and limitations of different forms of knowledge for solving different kinds of problems	2.217	2.218	0.989

* Statistically significant at the $p \leq 0.05$ level.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Paper ID #25934

Is Sociotechnical Thinking Important in Engineering Education?: Survey Perceptions of Male and Female Undergraduates

Maggie Swartz, Colorado School of Mines

Maggie Swartz is a graduating senior in Chemical Engineering with a minor in Public Affairs through the McBride Honors Program at the Colorado School of Mines. As a member of the McBride Honors Program for the past three and a half years, she is passionate about sociotechnical interfaces and human impacts in engineering. Her involvement with the Society of Women Engineers increased her awareness of the challenges facing female engineering students, both at the university level and as they pursue careers in industry. Graduating this December, she hopes to retain this knowledge for the benefit of herself and other women engineers as she pursues an industry career.

Dr. Jon A. Leydens, Colorado School of Mines

Jon A. Leydens is Associate Professor of Engineering Education Research in the Division of Humanities, Arts, and Social Sciences at the Colorado School of Mines, USA. Dr. Leydens' research and teaching interests are in engineering education, communication, and social justice. Dr. Leydens is author or co-author of 40 peer-reviewed papers, co-author of Engineering and Sustainable Community Development (Morgan and Claypool, 2010), and editor of Sociotechnical Communication in Engineering (Routledge, 2014). In 2016, Dr. Leydens won the Exemplar in Engineering Ethics Education Award from the National Academy of Engineering, along with CSM colleagues Juan C. Lucena and Kathryn Johnson, for a cross-disciplinary suite of courses that enact macroethics by making social justice visible in engineering education. In 2017, he and two co-authors won the Best Paper Award in the Minorities in Engineering Division at the American Society for Engineering Education annual conference. Dr. Leydens' recent research, with co-author Juan C. Lucena, focused on rendering visible the social justice dimensions inherent in three components of the engineering curriculum—in engineering sciences, engineering design, and humanities and social science courses; that work resulted in Engineering Justice: Transforming Engineering Education and Practice (Wiley-IEEE Press, 2018). His current research grant project explores how to foster and assess sociotechnical thinking in engineering science and design courses.

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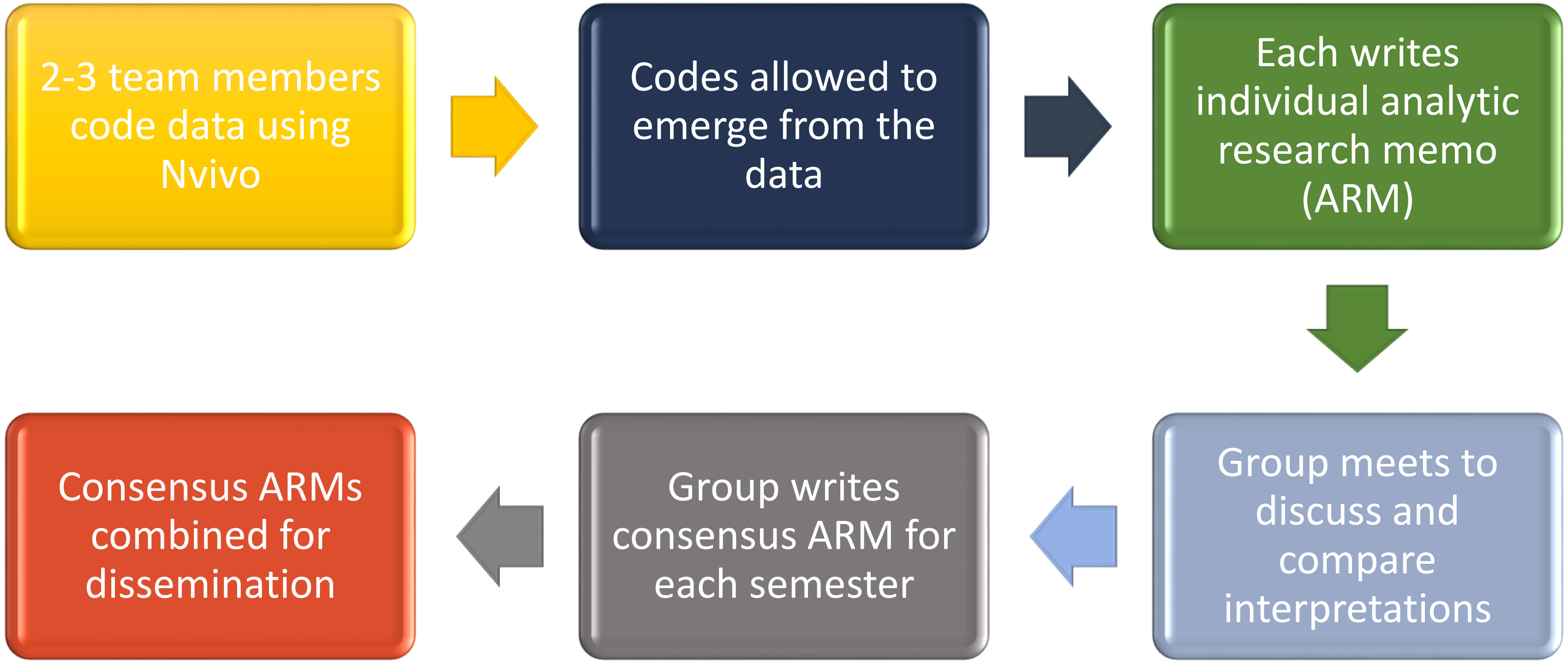
Analysis 2: Qualitative Analysis Process

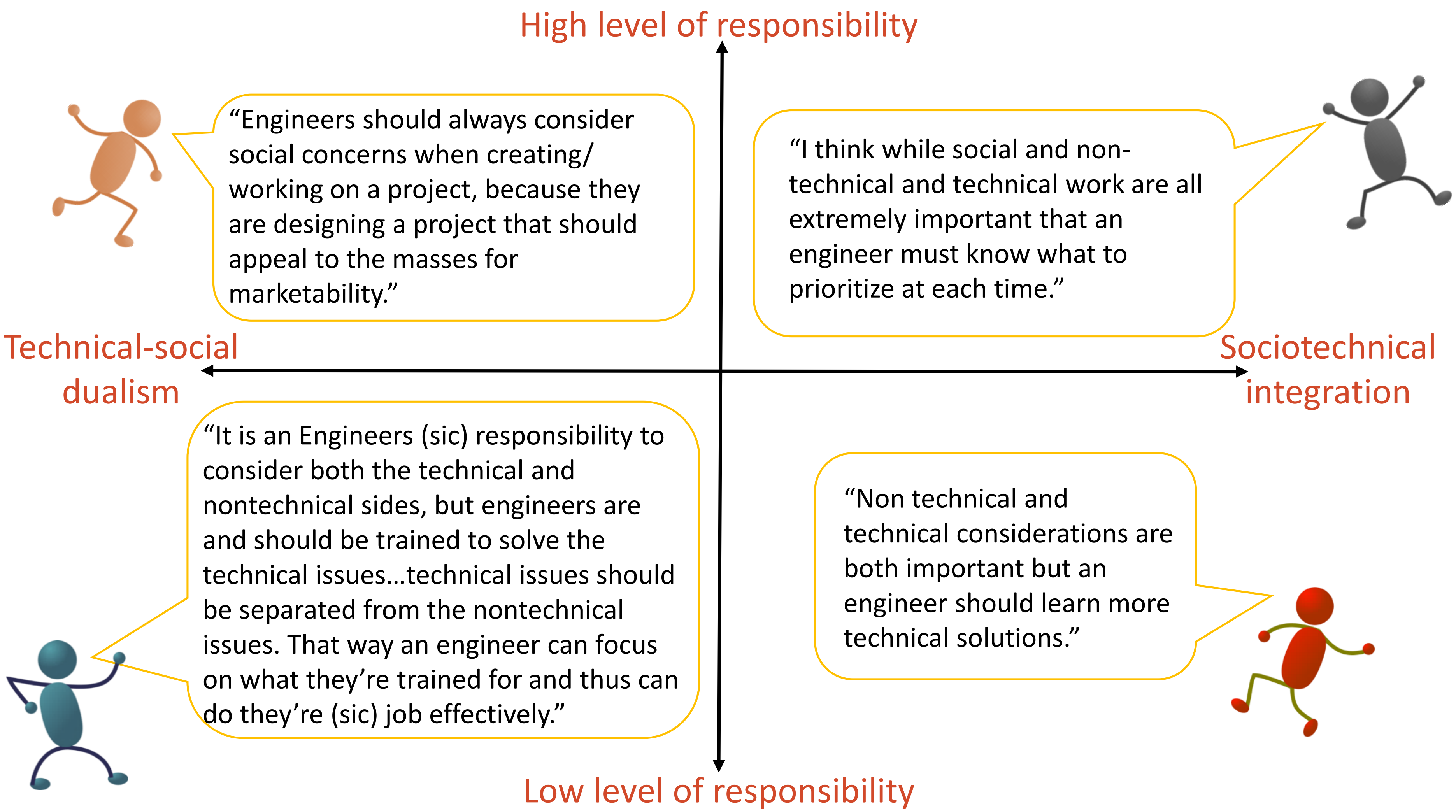


J. Case and G. Light, "Framing qualitative methods in engineering education research: Established and emerging methodologies," *Cambridge Handbook of Eng. Ed. research*, NY: Cambridge University Press, 2014.

Saldana, 2013 - The coding manual for qualitative researchers. Los Angeles, Sage.

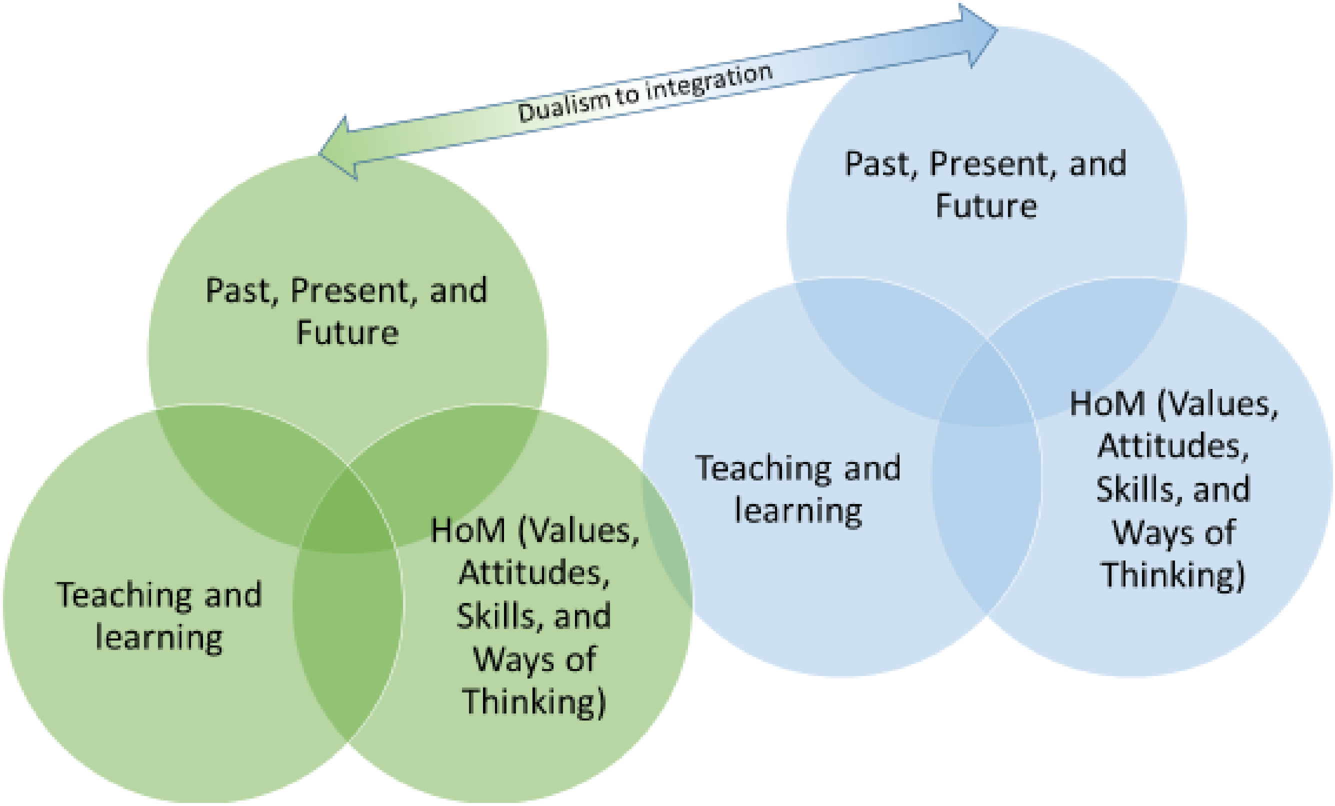
Analysis 3: Qualitative survey results

Fall 2018 Survey: 2-D Spectrum of Social and Technical Dimensions of Engineering



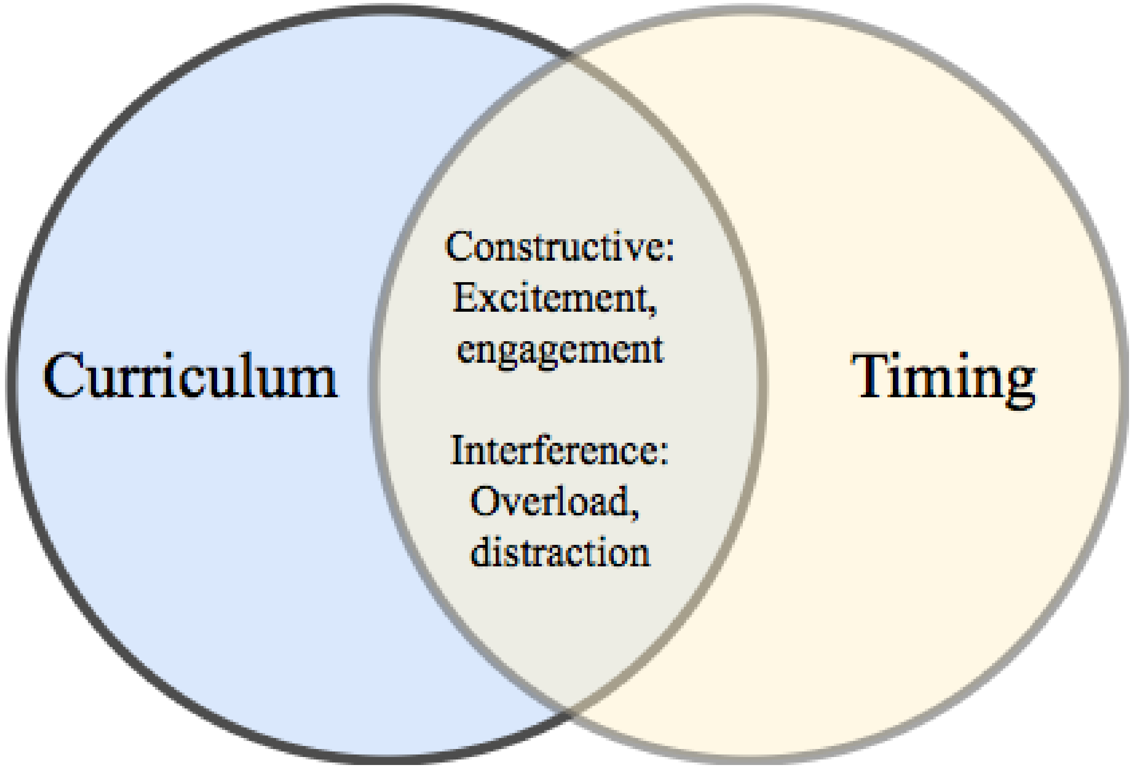
Analysis 4: Focus Groups

- 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



Back to Elements I-IV

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 (1st year) to Course 3 (3rd 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.

Back to Elements I-IV

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)