Sociotechnical Thinking in STEM Education

Acknowledgements

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- We also thank many former undergraduate research team members who have contributed to the knowledge we present today.

Welcome and Introductions

Who We Are: Research Team

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Who You Are: Workshop Attendees

- Please briefly introduce yourself:
  - Name
  - Teaching and/or research area
  - University

Agenda

- 11:00 (Mountain Time) Introductions
- 11:10 Overview of the project
- 11:25 Workshop goals, including participant goal-setting (work time)
- 11:35 Our experiences in three classes, intermingled with participant work time
- 12:35 Group sharing and feedback
- 12:50 Next steps
- 1:00 Workshop concludes

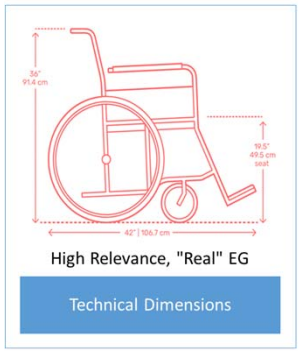
Project Overview

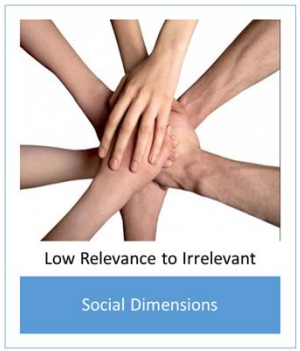
What Do We Mean By “Sociotechnical Thinking”?

“The interplay between relevant social and technical factors in the problem to be solved,” focusing on the problem definition and solution process (Leydens et al., 2018).

Our definition of *social* includes environmental, ethical, economic, health, safety, political, and cultural factors

Social-technical dualism ⟷ Sociotechnical integration





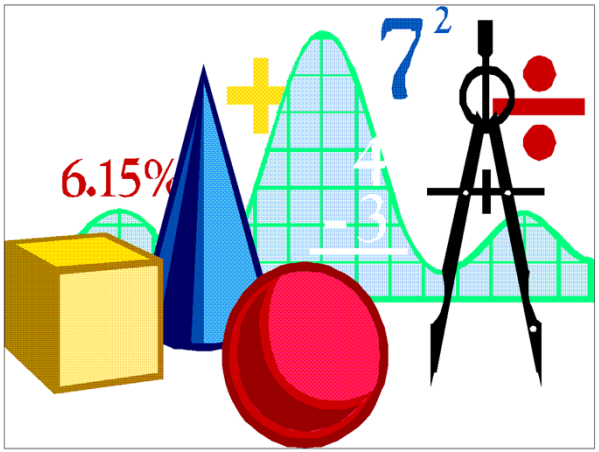
Why Emphasize Sociotechnical Dimensions?

"In our research, we found that more experienced engineers… had mostly realized that *the real intellectual challenges in engineering involve people and technical issues simultaneously.* Most had found working with these challenges far more satisfying than remaining entirely in the technical domain of objects."

(Trevelyan, 2014, pp. 49-51, emphasis added)

Slide from Leydens *et al.,* ASEE 2018

Why Emphasize Sociotechnical Dimensions?



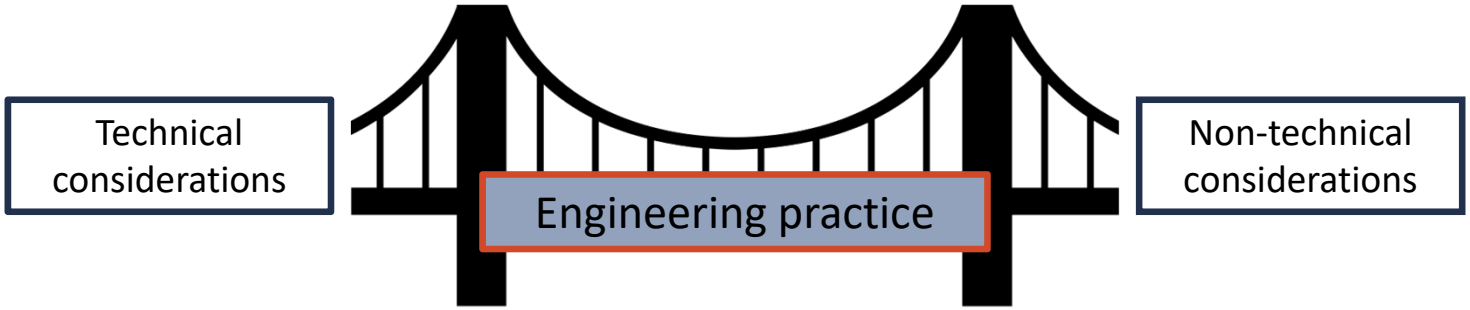
"Students often have vague images of professional engineering work, and the images they do have are strongly colored by the experiences in their educational careers [including navigating…] textbook, problem set, and text-based mathematics and science courses. As a result, students often ignore, discount, or simply do not see images of engineering that emphasize its nontechnical, noncalculative sides…"

(Stevens et al., 2014, p. 120).

Slide from Leydens *et al.,* ASEE 2018

Summary Motivation: Let's Bridge the Gap

(see also: Leydens et al., ASEE 2019; Claussen et al., ASEE 2019)



Operative Question: From the solution designed, who benefits and who suffers? Who is not even at the table?

Our Goals

Project-level

- Reconcile engineering education with engineering practice to better equip students
- Evaluate what works to increase the chances of positive impact

Workshop specific

- Increase the number of classes that incorporate sociotechnical thinking
- Create a community of interested faculty to support each other's efforts
- Get feedback to help us improve our dissemination

What We've Studied and What We've Found (1)

- We built a survey to try to measure sociotechnical thinking (ASEE 2018)

- We looked at results from that survey and found more questions than answers (ASEE 2019)
  - Impact of institution, year in school, etc. – hard to tease out
  - Impact of gender – a couple of significant differences

Paper ID #23071

Measuring Change over Time in Sociotechnical Thinking: A Survey/validation Model for Sociotechnical Habits of Mind

Paper ID #25605

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

Paper ID #25934

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

What We've Studied and What We've Found (2)

- We developed a new Interview Assignment to facilitate sociotechnical thinking in all three classes (ASEE 2019)
- We analyzed similarities and differences between real-world examples and sociotechnical thinking (ASEE 2020)

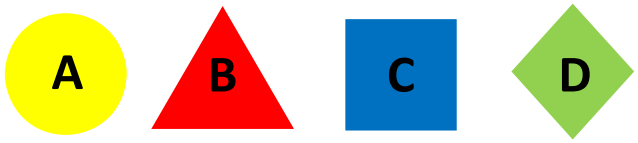
- We're finalizing two ASEE 2021 papers exploring
  - Engineering identity and sociotechnical thinking, and
  - Faculty reflections on integrating sociotechnical thinking

Workshop Goals

Participant Goals

- https://docs.google.com/presentation/d/1w9lx7nQN5XoZqq0nf4SCjKNCDQz5WyMB0QR0CTibw40/edit?usp=sharing (slides 3-6)

Within the Drive file, look for the slide with your breakout room letter/shape:

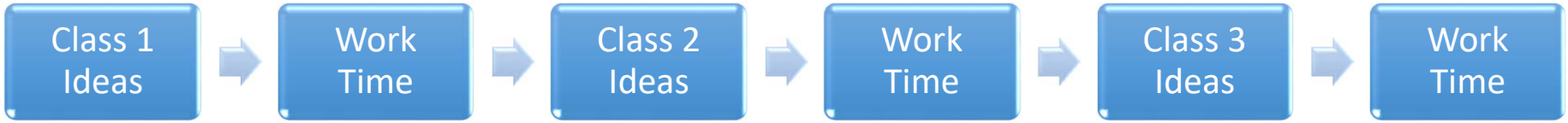


- (5 min) In breakout rooms, discuss any or all of these prompts:
  1. What do you know about sociotechnical thinking?
  2. Have you integrated sociotechnical thinking in your classes? If so, how, and what challenges and breakthroughs have you encountered?
  3. Are you aware of others integrating sociotechnical thinking and STEM in your university's programs?
  4. What do you hope to get out of this workshop?

- (5 min) Breakout groups report to the larger group

Experiences in our Classes

Organization of this Section

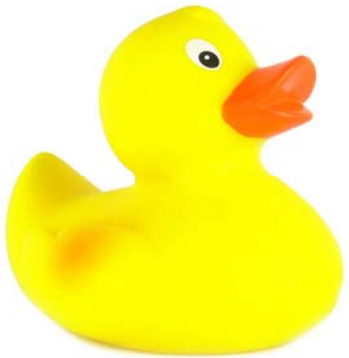


- Class 1: First year “Projects” course (CU-Boulder)
- Class 2: Second year “Intro to Mechanical Engineering” course (CSM)
- Class 3: Third year “Electromagnetics” course (CSM)
- Symbol key:
  - Toolbox 
  - Hurdles overcome 

Class 1: First-Year Engineering Projects (CU-Boulder)

Two examples of socio-technical problems with surprising solutions

1) The “Dutch Reach”
2) The Boulder County Duck Race



Example #1: How do you prevent getting “doored” on a bicycle?

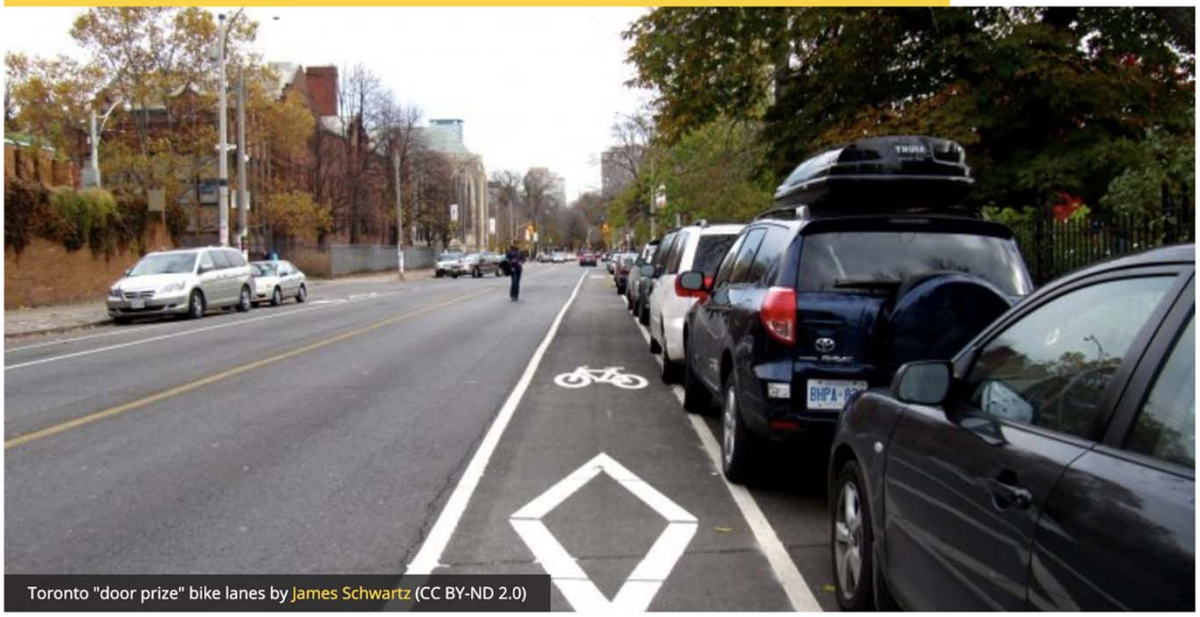
Brainstorm: If this was your First-Year Engineering Project this semester, what would you do?

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

Problem Definition #1: The Dutch Reach

ARTICLE BY KURT KOHLSTEDT

The Dutch Reach: Clever Workaround to Keep Cyclists from Getting "Doored"



Toronto "door prize" bike lanes by James Schwartz (CC BY-ND 2.0)

"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."

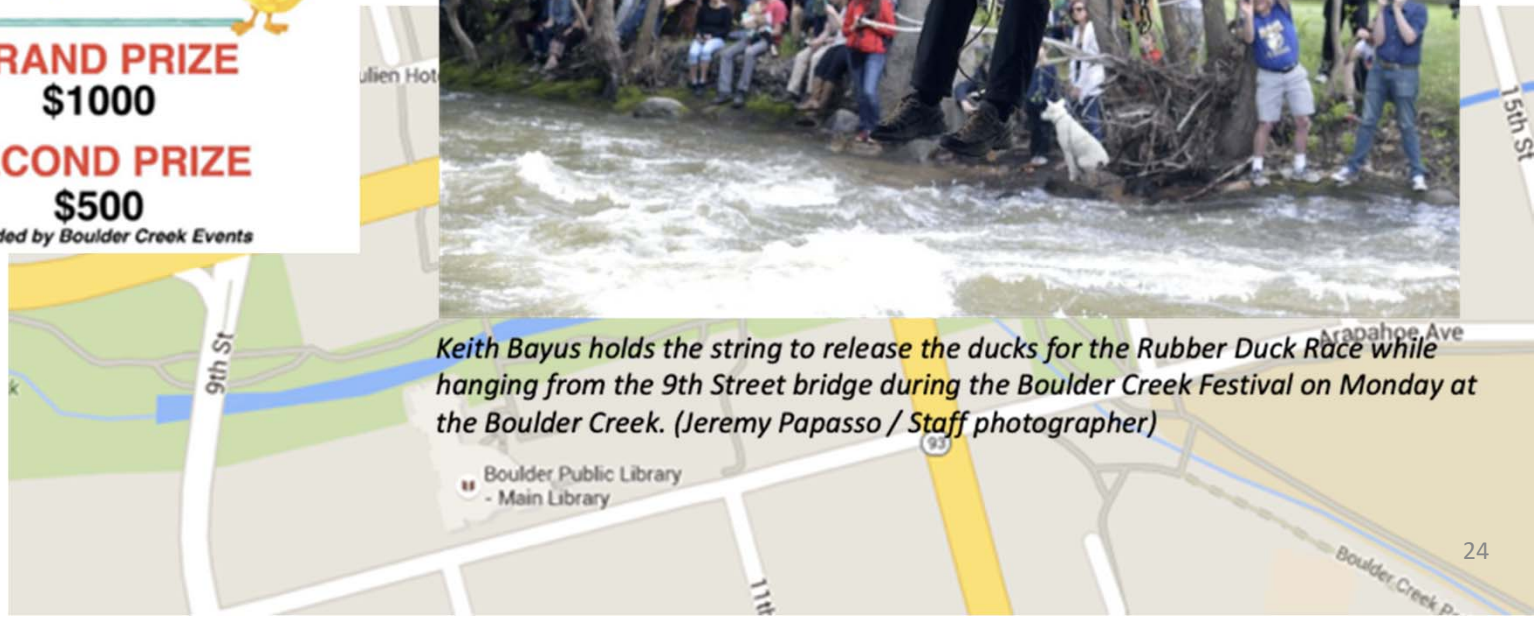
https://99percentinvisible.org/article/dutch-reach-clever-workaround-keep-cyclists-getting-doored/

Hurdles (Overcome): How to engage students in problem definition?

- Presenting the solution first did not work – no puzzle to be solved
- Instead: Ask students to brainstorm their own solutions first & share back with the class
  - Point out if the students default to a technical solution
- Use discussion of "social solutions" as launching point to discuss
  - impact of problem definition on potential solutions
  - efficacy of these solutions vs. purely technical ones
  - influence of cultural norms on how likely these solutions are to be effective
  - student design problems & engineering project definitions

Example #2: The Boulder Creek Duck Race

Keith Bayus holds the string to release the ducks for the Rubber Duck Race while hanging from the 9th Street bridge during the Boulder Creek Festival on Monday at the Boulder Creek. (Jeremy Papasso / Staff photographer)



Byars, M. (2015, May 25). They're quack: Rubber duck race returns to the Boulder Creek. *The Daily Camera*. Boulder, CO.

2010 Finish Line

2015 Finish Line

'Great duck escape': Rubber ducks still loose on fast-moving Boulder Creek

By Mitchell Byars

Staff Writer

POSTED: 05/26/2015 01:57:14 PM MDT | UPDATED: 3 MONTHS AGO

Byars, M. (2015, May 26). "Great duck escape": Rubber ducks still loose on fast-moving Boulder Creek. The Daily Camera. Boulder, CO. Retrieved from http://www.dailycamera.com/popular/ci_28191350?source=most_viewed

Problem Definition #2: The Boulder Creek Duck Race

How would you re-design the Duck Race Finish Line to be safer for everyone involved?

If this was your First-Year Engineering Project this semester, what would you do?

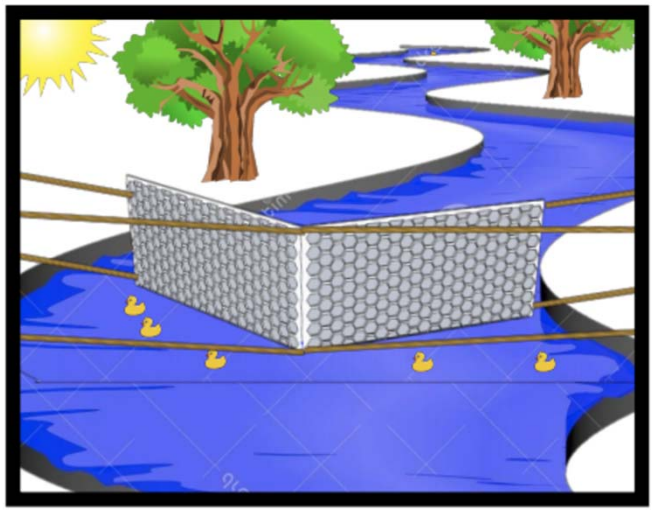


Diagram of “No Duck Left Behind” system from GEEN1400 Fall 2015

Problem Definition #2: The Boulder Creek Duck

Participant work time 1

- https://docs.google.com/presentation/d/1w9lx7nQN5XoZqq0nf4SCjKNCDQz5WyMB0QR0CTibw40/edit?usp=sharing (slides 8-11)

Format: 3 minutes of individual work followed by 5 minutes of discussion in breakout rooms. Please add breakout room discussion notes to the relevant slide for "Participant work time 1" and your breakout room on Drive.

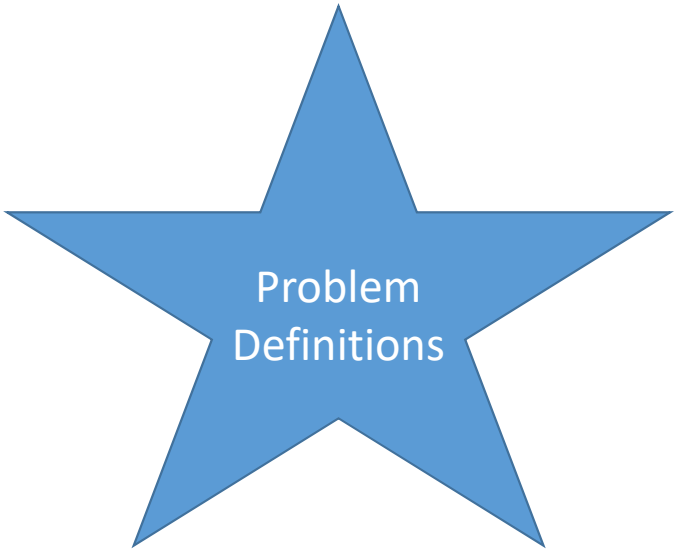
Prompts:

1. Are there problems – especially connected to your local community - that are tempting to answer through purely "technical" means, that could be answered via social/sociotechnical means as well?
2. Think about a class that you teach. Can you think of a way to use the (local) problem in your class?
3. What hurdles do you anticipate? How might you overcome them?

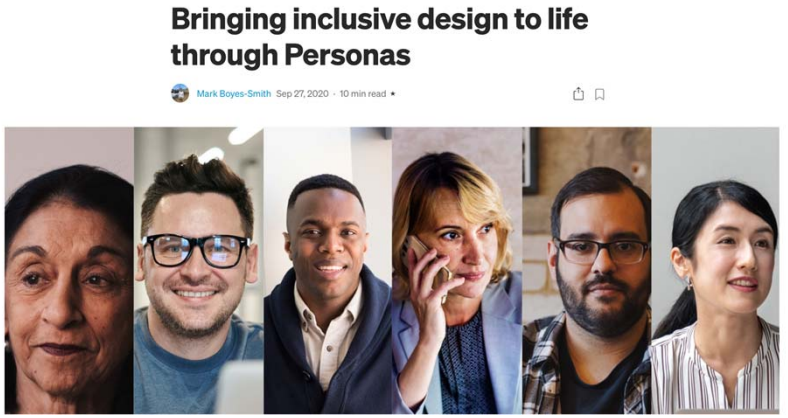
Class 2: Introduction to Mechanical Engineering (CSM, 200-level)

Two examples of socio-technical Integration into the Classroom

- Universal Design Example
  - Persona cards
  - Getting out of the building
  - Fixed documentary - optional
- Dollar Bill Example



Problem Definition #1: Universal Design Example



Tool used to find the right answer to a design challenge and problem definitions: The needs of users are personal and unique, meaning that sometimes a design decision taken for the benefit of one user may be detrimental to another.

- **Designers** must understand the materials and capabilities of the build technology
- **Engineers** must understand how to understand the design intent
- **Researchers** must be able to understand what users experience and use technical vocabulary to steer both designers and engineers in the right direction

The Principles of Universal Design

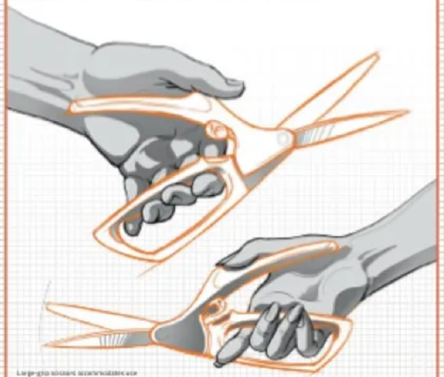
The design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design.

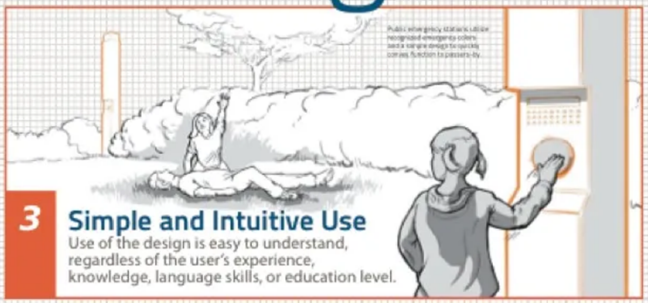
1 Equitable Use

The design is useful and marketable to people with diverse abilities.

2 Flexibility in Use

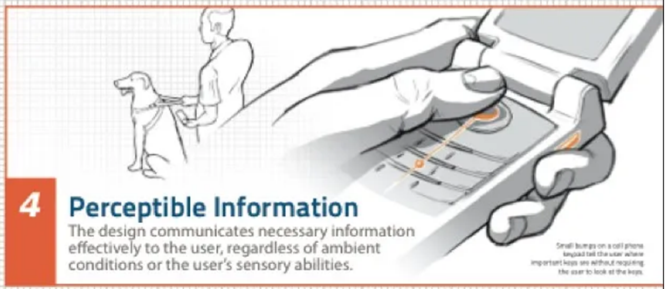
The design accommodates a wide range of individual preferences and abilities.





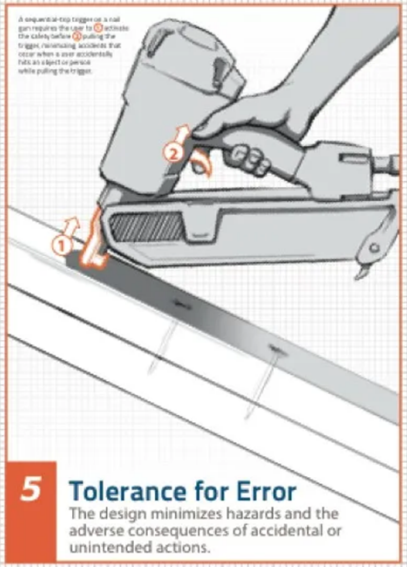
3 Simple and Intuitive Use

Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or education level.



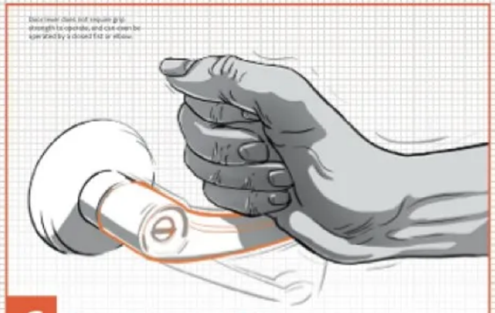
4 Perceptible Information

The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.



5 Tolerance for Error

The design minimizes hazards and the adverse consequences of accidental or unintended actions.



6 Low Physical Effort

The design can be used efficiently and comfortably and with a minimum of fatigue.

7 Size and Space for Approach and Use

Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.

Center for Universal Design at NC State

Web: design.ncsu.edu/cud | E-mail: cud@ncsu.edu

Tools

- **Building empathy – 'getting out of the building'**: Accessibility is truly a journey of understanding. It is essential to have buy-in from everyone involved to create a successful result. Achieving this buy-in can be challenging.
- **Tools to teach UD**: Persona cards
- https://uxdesign.cc/bringing-inclusive-design-to-life-through-personas-83ba26a41109
- 'Fixed' the documentary (5 minutes) - https://www.fixedthemovie.com/

Hurdles (Overcome): How to engage students in problem definition?

- **Universal Design (UD)** and other **design methodologies** are tools used for **inclusive design practices**.
- Universal Design does not solve sociotechnical integration into the curriculum, but is a tool to help students think about others and their needs.
- When linking UD to ST, my own personal experience felt similar to that of the *Imposter Syndrome.* I have taught UD in the classroom, but I have not taught ST as a fully integrated topic throughout a course or curriculum.
- **Instead** – Focus on UD as a stepping stone towards sociotechnical thinking.
- **Instead** – Create a support structure of faculty and students when trying to teach 'hard to teach topics' and discuss best practices and hardships of teaching these topics. We are not alone!

Problem Definition #2: Dollar Bill Example

- What are fundamental design flaws with the iBill design?
- Is this iBill accessible for all individuals?
- How would you design the iBill?

The US Treasury was ruled to discriminate against blind and visually impaired people because their notes were all the same size and the numerals were hard to read. The Treasury has had to distribute free currency readers to eligible individuals at significant cost.

https://www.youtube.com/watch?time_continue=45&v=hwzzvvy8T5A

Hurdles (Overcome): How to engage students in problem definition?

- Students were engaged with the real world example of the dollar bill – but did not make the clear connection between social and technical thinking.
- Student's problem definitions did not suggest true sociotechnical integration.
- Students did not take into consideration other social aspects such as ethics, safety, culture and society as a whole. Universal Design focuses on impairments, but not the full social scope. UD is just one tool.
- **Instead**: Ask students to speak to individuals outside the building and write a reflective piece on engagement with others.
- **Instead**: Ask students to present on their ST findings in front of their peers to show the breadth of discussion and thought. Reflections.

Summary – from my experiences

- Focus on UD as a stepping stone towards sociotechnical thinking.
- Ask students to speak to individuals outside the building and write a reflective piece on engagement with others.
- Ask students to present on their ST findings in front of their peers to show the breadth of discussion and thought. Reflections.
- Create a support structure of faculty and students when trying to teach 'hard to teach topics' and discuss best practices and hardships of teaching these topics. We are not alone!

Participant work time 2

- https://docs.google.com/presentation/d/1w9lx7nQN5XoZqq0nf4SCjKNCDQz5WyMB0QR0CTibw40/edit?usp=sharing (slides 13-16)

Format: 3 minutes of individual work followed by 5 minutes of discussion in breakout rooms. Please add breakout room discussion notes to the relevant slide for "Participant work time 2" and your breakout room on Drive.

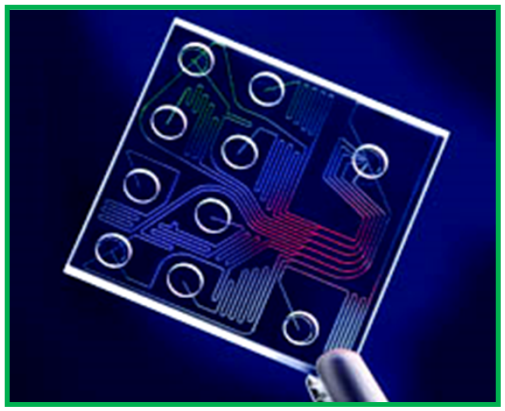
Prompts:

1. Can you ask your students to re-define problems around open-ended challenges to encourage sociotechnical thinking?
2. What types of examples do you use to engage students socially, in class? Do these examples promote sociotechnical thinking?
3. How might you enhance sociotechnical thinking in your class and throughout the whole problem defining and solving process?

Class 3: Fundamentals of Engineering Electromagnetics (CSM, 300-level)

Micro-insertions of sociotechnical engineering throughout the course

- **Course design**: Each of the three units of the course is structured around a single application of electromagnetism.



Lab-on-a-chip

Solar cells (Image: phys.org)

5G cellular networks

Micro-insertions of sociotechnical engineering throughout the course

- **Course design**: Each of the three units of the course is structured around a single application of electromagnetism.
  - Enables discussion around who benefits from a technology, who does not benefit, who is not included
  - Equips students to consider more than just the "obvious" impacts of technology

Sample class activity: Brainstorming who benefits and who is harmed by lab-on-a-chip diagnostics

First-order sociotechnical thinking (Direct and obvious cause and effects)	**Second-order sociotechnical thinking** (Social consequences of a technology beyond direct cause and effects)
Improved health outcomes for patients unable to access traditional labs	
Potential loss of jobs for people currently employed in lab (medical, forensic) facilities	

Andrade and Tomblim, 2019, *Proceedings of the 2019 American Society of Engineering Education Annual Conference;* Image from 123RF.com

Sample class activity: Discussion – solar cells

Please take 5 minutes to discuss the following questions in your groups:

1. In the short and long term, who benefits from solar energy?
2. Who does not benefit or is harmed?
3. Who is left out of the conversation about solar energy?
4. **How would your answers to the questions above above impact your design of such a system?**

Image from phys.org

Failure to explicitly argue or present evidence that engineering *is* sociotechnical

I thought that I could just teach engineering as ST without having to explicitly provide evidence or vocabulary to treat it as such.

I began to use the slides created by Janet to explain and motivate sociotechnical thinking.

SC1

Class assignments made visible students' discomfort with ambiguity and questions around expertise

(Some) students expected me to be an expert on all technologies *and* their sociotechnical dimensions.

They did not like it when the sociotechnical dimensions were "speculative" or not clearly supported with evidence.

Wrestling with issues of ambiguity and expertise is one of the objectives of these course interventions!

I also had to learn to be comfortable with being seen as a non-expert.

"I think that with the problem motivation [of lab-on-a-chip], it doesn't seem as though she has a deep understanding of any of the problem motivation. Like lab-on-a-chip when she has a superficial understanding of it, but we probe deeper, she doesn't actually know anything about it… which makes it challenging to actually get into conversations about stakeholders and Socio-technical Engineering. **Because you really do need to understand what the impacts of this technology are to be able to discuss them effectively.**"

- Gerald (pseudonym), Fall 2019 EENGR 386 focus group

Participant work time 3

https://docs.google.com/presentation/d/1w9lx7nQN5XoZqq0nf4SCjKNCDQz5WyMB0QR0CTibw40/edit?usp=sharing (slides 18-21)

Format: 3 minutes of individual work followed by 5 minutes of discussion in breakout rooms. Please add breakout room discussion notes to the relevant slide for "Participant work time 3" and your breakout room on Drive.

Prompts:

Brainstorm a micro-insertion that you might use in your targeted course.

Some things to consider as you work:

1. What are your sociotechnical learning objectives for this activity?
2. What is the structure of the activity? (What will students be *doing*?)
3. Where will this fit into your course design?
4. What might an assessment look like for this activity?

Breakout room reporting

- Each breakout room has an opportunity to report back on 1-2 of the ideas they discussed during participant work time 1-3

Idea Synthesis

Group Discussion

https://docs.google.com/presentation/d/1w9lx7nQN5XoZqq0nf4SCjKNCDQz5WyMB0QR0CTibw40/edit?usp=sharing (slide 23)

Format: 3 minutes of breakout room discussion time followed by each breakout room reporting back on one question to the full workshop.

Prompts:

1. Which of the examples that we presented today resonated most with you, and why?
2. We have discussed localizing problems with potentially non-technical solution, exploring the broader problem definition space, types of examples, and micro-insertions. What other ways might you suggest to the group for promoting sociotechnical thinking?
3. What concerns do you have about encouraging sociotechnical thinking in your classes?
4. What goals do you have as a result of today's workshop?

Paths Forward

- Given what you've heard from us and what we have heard from you, how can we all support each other moving forward?
  - We believe finding your allies is important to success. Can we find a way to keep communicating, sharing ideas, etc.?

Next Steps

Post-workshop survey

Please help us to improve this workshop by visiting the link below and answering the three questions there:

https://forms.gle/F2TDQbDAJNvyiSRw8

1. What questions do you have about what we have shared today?
2. What part(s) of the workshop were most helpful?
3. What suggestions do you have to help us to improve this workshop and to promote sociotechnical thinking among our colleagues and students?

Let us Know How it Goes!

https://www.mines.edu/sociotechnicaleducation/

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