Engaging an Entrepreneurial Mindset Though Open-Ended Projects in the Sophomore Year

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Entrepreneurial Mindset (EM)

- Interest in the belief that people need to develop entrepreneurial skills to help advance society[1,2]
- In 2005, the National Academy of Engineering published their recommendations for training students to develop an EM[3]
- The Kern Entrepreneurial Engineering Network associates an EM with an ability to[4]
  - Be curious about our changing world and explore a contrarian view of accepted solutions.
  - Regularly connect information from many sources to gain insight and manage risk.
  - Create value from unexpected opportunities as well as persist through, and learn from, failure.

How to Incorporate EM in Engineering Courses

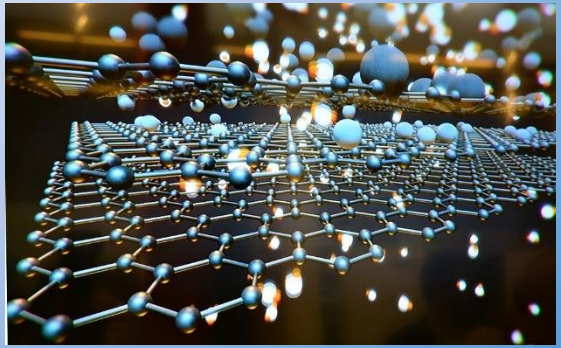
- Be curious about our changing world and explore a contrarian view of accepted solutions.
  - Ask questions with no clear answer
- Regularly connect information from many sources to gain insight and manage risk.
  - Require the review of literature on a topic
- Create value from unexpected opportunities as well as persist through, and learn from, failure.
  - Ask for new ideas and encourage trying out new ideas if initial plans fail

Open-Ended Projects

Course Details

- Materials in Engineering Systems (Fall)
  - Basic introduction to materials science (gases, liquids, and solids)
- Fluid Thermal Systems (Spring)
  - Introduction to thermodynamics, fluid dynamics, and heat transfer

- Sophomore-level courses
- ~18 students (no TAs)
- Projects take place one month before the end of a 14-week semester



Materials in Engineering Systems

- After discussing the mechanical properties of metals
  - Elastic vs plastic deformation
  - Stress-strain diagrams
  - Fatigue
  - Fracture toughness

this activity was launched

Back to the Future: Saving Boston from Molasses

How dangerous can a container of molasses be?

On January 15, 1919, a molasses storage tank in Boston ruptured, creating a molasses wave traveling at 35 mph to flood the city and kill 21 people. But you and Doc Brown can save these people with your DeLorean time machine!

U.S. Industrial Alcohol owns this tank, which stores molasses from the Caribbean for the production alcohol for ammunitions. Travel back to January 14, 1919, and it is your job to convince the chairman of the company's board, Charles Edward Adams, to replace his tank with a tank made from another, better but cost-effective material.

Design your new tank: choose material, thickness of tank walls, and cost of this tank

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Boston Molasses Disaster Learning Objectives

- Identify factors that affect material failure
- Apply yield strength to product design
- Select a material for an application, considering economics and safety
- Integrate information from several reference sources to gain insight
- Assess and manage risk
- Persist through and learn from historic failure

Background Information

- Tank must be: 50 ft tall, 90 ft diameter (students determine the thickness)
- Must store 2,300,000 gallons of molasses
- Density of molasses: 1400 kg/m^3
- Your design must include a factor of safety of 2
- The tank is 200 ft from the Charles River

- Helpful hints on hoop & longitudinal stress provided in an appendix

Back to the Future: Saving Boston from Molasses

- Deliverables & Assessment:
  - 2-page technical memo (individual)
  - 5 minute presentation with persuasive pitch (group)
  - Rubrics created
- Teaming: Groups of 3 students
- Deployment details
  - Day 1: The module will be introduced during the last half of class (~30-45 mins)
  - Day 2 (1 week later): ~30-45 minutes of class time will be provided to work on the project
  - Day 3 (1 week later): Students groups will present their findings (~45 mins) & Class Debriefing

Day 1: Selecting Materials & Preliminary Research

- In groups of 3, students decide on 3 unique materials that could feasibly be used to replace the steel used in the original tank
- Each group member takes ownership of one material
- Students begin searching for material properties using the textbook, reference books in the library, and/or *reliable* internet references

Assignment due in one week: Preliminary calculations for the tank wall thickness and cost, and a list of pros & cons on your material.

Day 2: Discuss Calculations & Work on Presentations

- Prior to class, instructor provides individual feedback on preliminary calculations
- Group members share the information they collected
- Group selects one material to recommend and prepares presentation

Assignment due in one week: Individual tech memo & group presentation

Day 3: Presentations

- Groups present for ~5 minutes to pitch their replacement material
- Individual memo: students focus on the material they selected on Day 1 to:
  - Provide specific, referenced details on this material (cost, strength properties, fracture properties, corrosion properties, environmental concerns). Use this information to discuss the pros and cons of using this material.
  - Provide the tank thickness necessary and the total cost of the material to make this tank.
  - Explain why was/wasn't this material chosen to replace the molasses tank.

Fluid Thermal Systems

- After discussing Bernoulli's Equation
  - Major and minor losses
  - Pumping power
  - Reynold's Number
  - Friction factor

this activity was launched

Fluids Flowing Everywhere!

A faulty pipe flow system is never a good situation. Now that you have learned about fluid flow systems, it's your job to design your own flow system that will function properly!

You just started an internship at my consumer goods production facility, and I need you to design a fluid flow system for our factory. In groups of three students, you will be assigned a different fluid flow scenarios to investigate:

- Fluid flow properties, frictional losses, pipe flow system design, pump power required, pipe material, market advantages associated with the pipe material, and an overall cost for the flow system

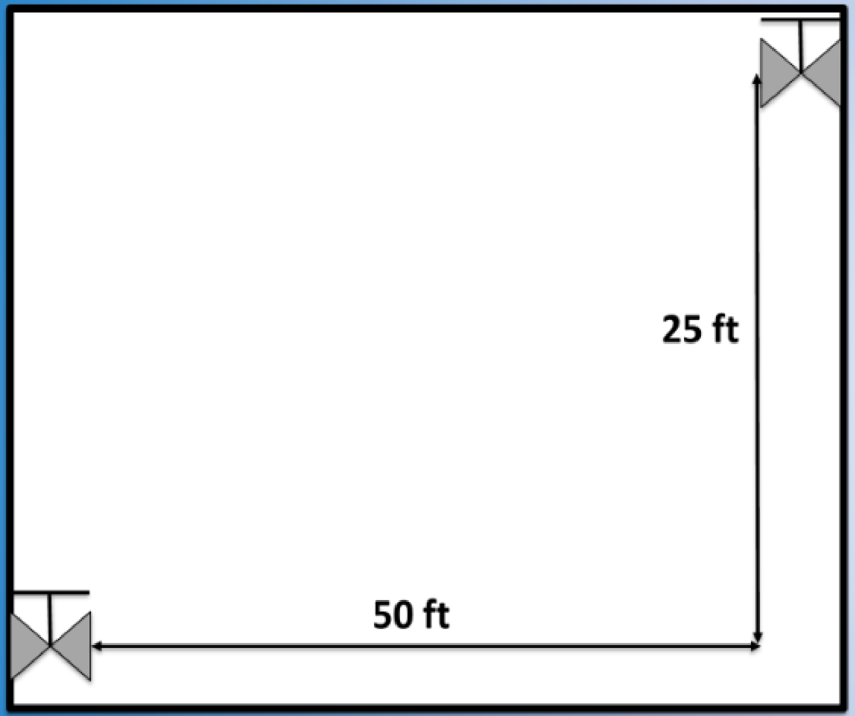
Designing a Fluid Flow System Learning Objectives

- Integrate information from many sources to gain insight
- Identify opportunities to save costs
- Apply creative thinking to ambiguous problems
- Apply systems thinking to complex problems
- Evaluate technical feasibility and economic drivers

Scenario Options

- Design a flow system for transporting:
  - Phenol, to later be mixed with formaldehyde in a reactor to produce phenolic plastic.
  - Milk, to later be mixed with sugar, cocoa butter, and other proprietary ingredients to make chocolate.
  - Ethylene glycol, to be mixed with water to make antifreeze.
  - Glycerin, to be mixed with sugar and alcohol to make soap.
  - Ethanol, to be mixed with water and Carbopol to make hand sanitizer.
  - Acetone, to be mixed with water and proprietary ingredients to make nail polish remover.

Background Information



- Based on your scenario, a fluid flow system must be designed that is capable of:
  - Transporting your fluid 50 ft horizontally and 25 ft vertically upwards at 12 L/s from a storage tank to a mixing tank.
  - Both tanks are open to the atmosphere, and the system must have valves of your choosing at the exit of the storage tank and at the inlet of the mixing tank.
  - Consider different design and pipe material options, keeping in mind safety and cost.

Fluids Flowing Everywhere!

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Day 1: Preliminary Research

- In groups of 3, read over group scenario
- Students begin searching for fluid properties using the textbook, reference books in the library, and/or *reliable* internet references

Assignment due in one week: Tentative design idea, fittings used, pipe material, and preliminary calculations for the pipe diameter and pump power

Day 2: Discuss Calculations & Work on Presentations

- Prior to class, instructor provides group feedback on preliminary calculations
- Group revise their design as needed and prepares presentation

Assignment due in one week: Individual tech memo & group presentation

Day 3: Presentations

- Groups present for ~5 minutes to pitch their flow design
- Individual memo: students focus on the material they selected on Day 1 to:
    - Describe the pipe flow system (pipe material, pipe diameter, design with fittings) and why you choose the materials/size/fittings that you described.
    - Explain the pumping power needed for this system to function.
    - Provide the cost for this system. Explain if this is a reasonable cost.
    - Summarize why this system is the best option for out factory.
    - *Bonus*: Find a pump that is capable of providing the pumping power needed and would connect within the pipe system you have created, and include the manufacturer, model number, and cost of that pump.

Instructor-Observed Results

- Students were excited to work on real-life applications
- Students enjoyed investigating materials and fluids that were not otherwise discussed in class
- Students thought outside the box
- Student Feedback
    - Materials in Engineering Systems
    - "I liked how relevant the subject matter was. I feel like this is information I will think about in the real world rather than memorize for a class."

    - Fluid-Thermal Systems
    - "The pipe project was an enjoyable way to practice applying our most recent learnings."
    - "More projects because those kept the course interesting and allowed to apply what we were learning to real world situations."

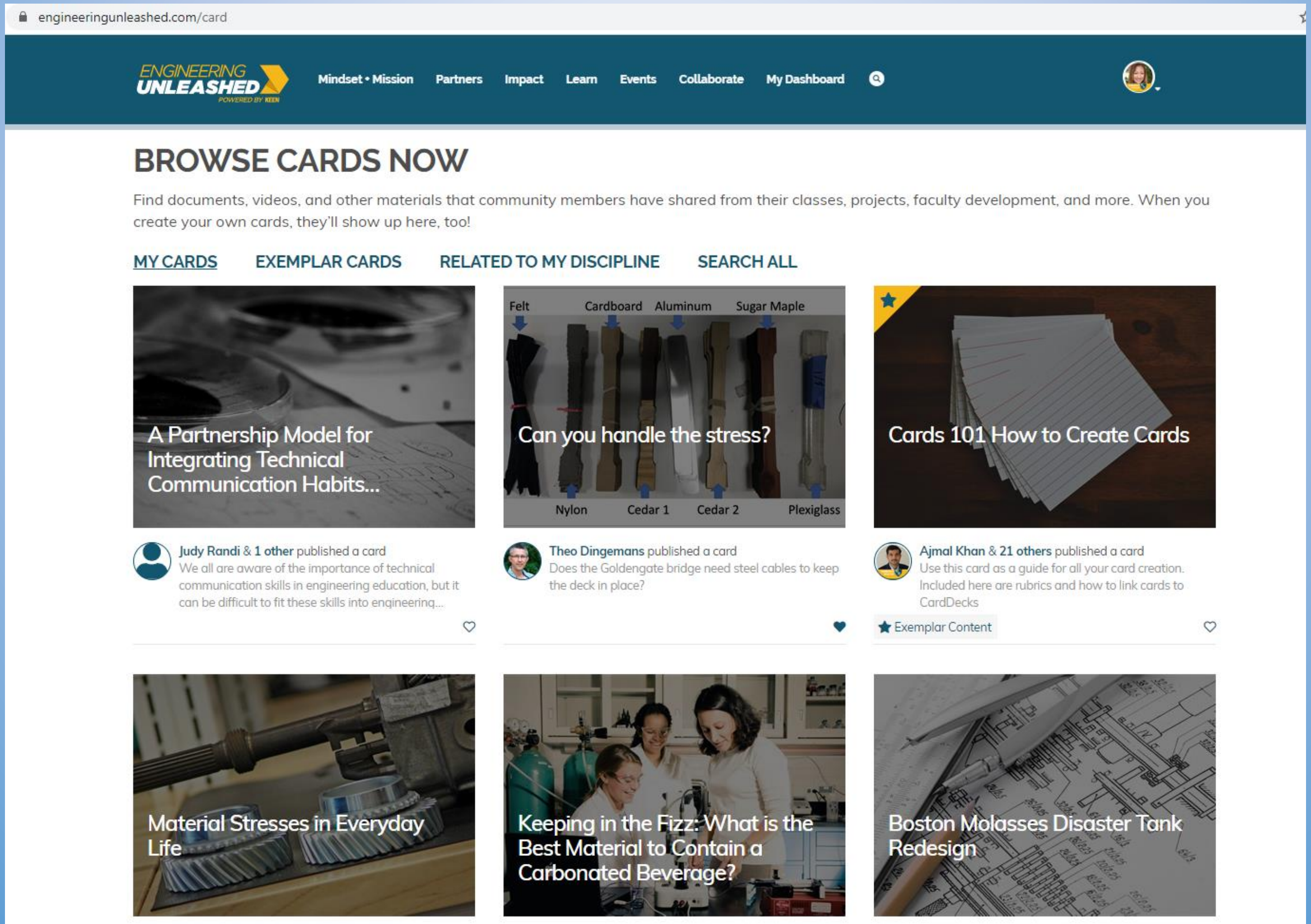
Implementation Tips

- Consider providing calculation hints on Day 1
- Grade preliminary calculations for effort
- Consider walking students through sample data on Day 2
- Make sure to remind students to be persuasive in their presentations
- Instead of oral presentations, students could be required to make a poster

Engineering Unleashed Resources

https://engineeringunleashed.com/

Make an account for free!



Links to Cards

Boston Molasses Tank Design

Design a Fluid Flow System

Need to be logged into EngineeringUnleashed.com

References

1. B. Zupan, F. Cankar, and S. Setnikar, "The development of an entrepreneurial mindset in primary education," in *European Journal of Education*, 2018, vol. 53, no. 3, pp. 427–439.
2. S. Rodriguez, and H. Lieber, "Relationship Between Entrepreneurship Education, Entrepreneurial Mindset, and Career Readiness in Secondary Students," in *Journal of Experiential Education*, 2020, vol. 43, no. 3, pp. 277–298.
3. National Academy of Engineering, "The Engineer of 2020: Visions of Engineering in the New Century," in The National Academies Press, Washington DC, 2005.
4. Engineering Unleashed, “The Entrepreneurial Mindset,” https://engineeringunleashed.com/mindset