RIEF: Improving Engineering Mechanics Self-Efficacy By Focusing On Abstracting The Physical World As A Precursor To Analysis

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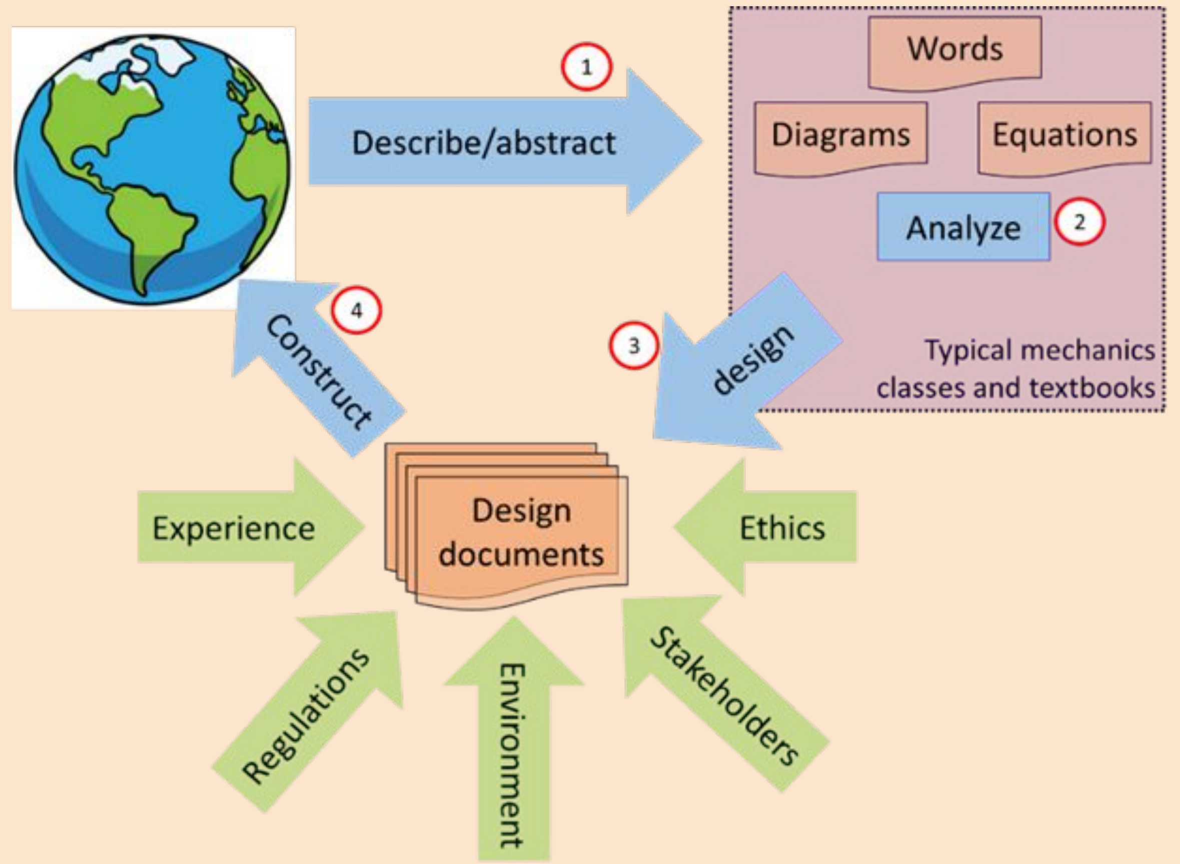
SCAN ME

Introduction and Research Questions

We aim to strengthen connections students make between coursework and the physical world by empowering students to start with the generalized skill of problem definition and scoping as they work with physical models in a foundational engineering course. This work is guided by two main research questions:

1. In what ways do teaching students how to abstract the physical world affect their problem solving self-efficacy in a basic mechanics course, and to what extent do students build direct connections between the physical world they live in with the mechanics models they will use in their studies?
2. In what ways do showing students how to abstract the physical world into tractable engineering science problems affect their future-oriented motivation, and to what extent do students make connections between what they learn and the physical world they will work in upon graduation?

Commonly used Engineering Mechanics textbooks present students with clearly defined problems with all the information needed to solve the problem. This approach skips the first part of the problem solving process

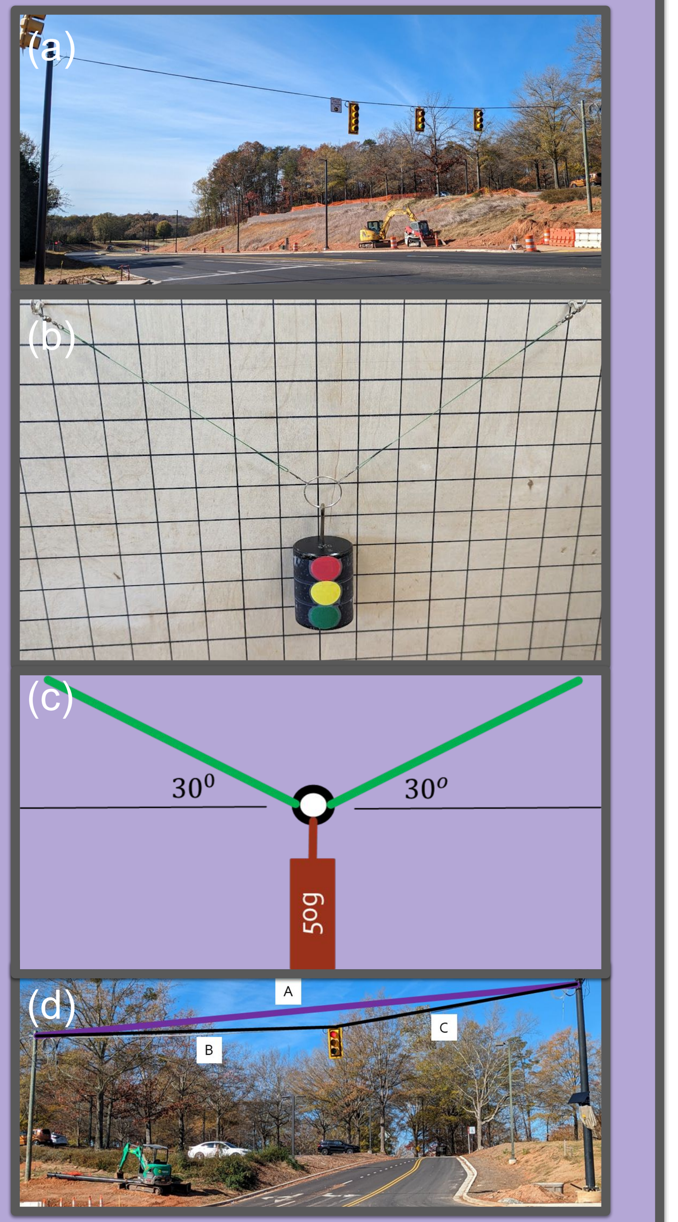


Research Methods

- Mixed methods approach using surveys, interviews, observations, and course artifacts
  - Surveys: Students' self-efficacy in engineering mechanics problem solving (Bandura, 1977) and future-oriented motivation (Kirn and Benson, 2015)
  - Course artifacts: Problem-solving skill development
  - Interviews, observations: Relationship between physical models, problem abstraction, real-world applications and students' perceptions of their future in engineering (Kirn and Benson, 2018).
- Baseline data on problem-solving self-efficacy (average and standard deviations for survey constructs) for students in sophomore-level statics using a previously validated survey (Grigg and Benson, 2015) for comparing before and after the implementation of physical models in the course and between civil engineering (CE) majors and non-majors.

Study Context

- Sophomore level statics course for civil, environmental, biosystems, biomedical, and industrial engineering; Multiple course sections of ~40 students each
- Lesson plan:
  - **Motivation:** Students select items to examine in the model urban area, which serves as context for the topic of the day.
  - **Question:** Students pose questions about the selected model item. Questions will be open-ended to allow students the space to explore.
  - **Focus:** Instructor guides the discussion toward a question related to the topic of the day.
  - **Abstraction:** The students would identify a particular component of the model item to analyze and discuss how to represent it on paper. The instructor would introduce the relevant theory as needed.
- Assessment: PROCESS rubric (Grigg and Benson, 2015) adapted as needed to capture problem abstraction:
  - Problem definition – identify parameters, constraints, assumptions, and outcomes.
  - Representation and Organization – sketch the problem showing all problem parameters; identify equations, parameters, variables etc.
  - Calculations – manipulate equations, show working, establish solutions.
  - Evaluate Solution – Check for accuracy and units
  - Solution Communication – Indicate final answer, check for reasonableness, and justify solution.
  - Self-assessment – Rate comfort with your understanding of the problem and solution.



Example Class

Problem: Traffic lights suspended by cables. (Image (a) taken from on campus)
Prior Knowledge: Cables can support forces in tension
Learning objectives: (1) Explain the concept of forces as vectors and (2) Solve 2-dimensional static equilibrium problems
Prompt: how strong do the cables need to be to support the traffic lights?
Questions to guide discussion:
- -What do we mean by "how strong?"
- What information would we need to solve this problem?

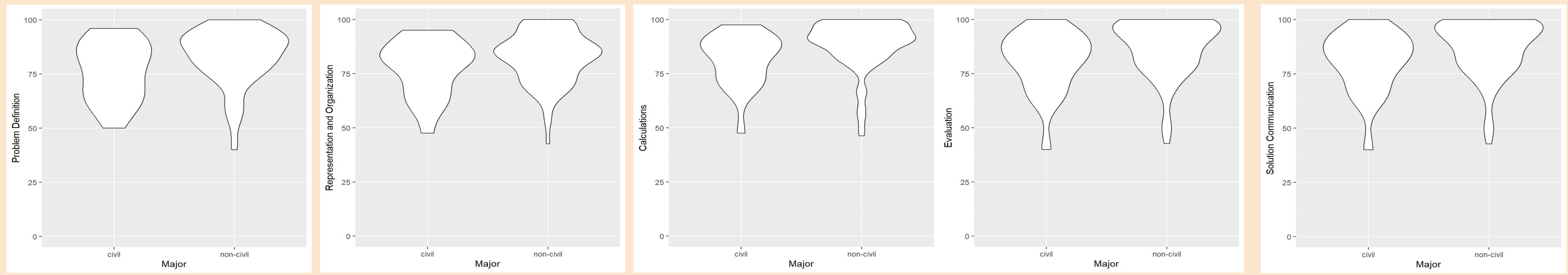
Model interaction: Students work in groups to experiment with a model traffic light consisting of a weight supported by two cables (image b)

Questions to guide experimentation:
- How do the forces vary with the cable angles?
- Can you make the cables perfectly horizontal?
- Are the forces inthe cable greater or less than the weight of lights?

Theory: Instructor introduces the concept of vectors, free body diagrams, and static equilibrium.
Problems: Students work in groups on a simple problem related to their model (image c) followed by a full scale problem with more complex geometry (image (d) taken from campus).
Questions for next time: Students are given problems to solve before the next class and questions to prompt deeper analysis of the problem.
- Why are traffic light cables relatively flat?
- What are the design tradeoffs when deciding on the cable angles?

Preliminary Results

Problem-solving self-efficacy survey results for students taking statics in Spring 2024 (*n* = 114) were analyzed based on steps in the PROCESS rubric: Problem identification, Representation and Organization, Calculation, Evaluation, and Solution communication. Distribution of self-efficacy scores for each problem solving step are shown below (vertical indicates minimum to maximum; horizontal indicates frequency for CE majors and non-majors. Results show high levels of confidence for each problem solving skill for both groups.



Future Plans

The new course compares student attitudes, motivation, and problem-solving skills before and after implementation of course focused on problem abstraction.

- Students in the existing statics course were surveyed to identify physical contexts of interest to them; this will inform models and culturally relevant contexts to be used in the new course.
- Class activities and timelines will incorporate problem abstraction, such as developing problem statements from physical models.
- Student solutions to problems will be assessed using the PROCESS rubric (Grigg and Benson, 2015), and problem-solving self-efficacy will be assessed using existing survey based on PROCESS rubric.
- Students' future-oriented motivation will be assessed to examine connections students make between problem solving contexts and tasks in the new course and their future as engineers using an existing survey (Kirn and Benson, 2015) and interviews.
- Comparisons between existing and new course outcomes will be made for students' future-oriented motivation (survey, interviews), problem solving self-efficacy (survey, interviews) and problem-solving skills (students' solutions assessed using the PROCESS rubric).

References and Acknowledgement

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