Connecting Industry to Mathematics Instruction
NSF ATE Award # 1954291

Loads of Steel

A Develop Understanding Task

Purpose: In this activity, students will work with SteelFab, Inc. engineers to determine the thickness of steel plates that need to be fabricated to ensure it is structurally sound and economically efficient. Students will take load information provided by the Engineer of Record to develop steel-to-steel connections. Using function composition and right triangle trigonometry, students will calculate the forces in each brace. Then, using Euler's Equation to determine the max compression, students will select an appropriate plate thickness to prevent buckling. Using Excel and information from SteelFab estimators, students will pull together costs to create a bid/budget to fabricate the steel plates they have designed.

In partnership with

WAKE TECH

WAKE COUNTY PUBLIC SCHOOL SYSTEM

WakeEd PARTNERSHIP

Career Field: Engineering/Architecture (SteelFab, Inc)

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NC Math 4 Standards:

- ➔ *NC.M4.AF.1* Apply properties of function composition to build new functions from existing functions
  - ➔ *NC.M4.AF.1.2* Execute a procedure to determine the value of a composite function at a given value when the functions are in algebraic, graphical, or tabular representations
- ➔ *NC.M4.AF.2* Apply properties of trigonometry to solve problems

Unit Alignment:
NC Math 4 - Unit 2 (Functions)

Common Core State Standards for Mathematical Practice

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
6. Attend to precision.
8. Look for and express regularity in repeated reasoning.

Prerequisite Skills

- Use the Pythagorean Theorem to find missing sides of a right triangle
- Set up right triangle trigonometry ratios
- Basic understanding of forces on a structure (to be discussed in the Launch video)

Time Required

The time required to complete this activity is approximately 120 minutes.
If 90-minute period, suggest Launch Part 1, Explore Part 1, and Discuss Part 1 on the first day for an entire class period. Launch Part 2, Explore Part 2, and Discuss Part 2 for half a period the following day.

Materials Needed

- Student Activity Sheet - Student Activity Sheet - Activity Sheet Answer Key
- Excel template for cost analysis - Estimating Cost Excel Template - Excel Answer Key

Goals & Objectives

- Students will be able to identify careers, education requirements, soft skills, etc. relevant to the task
- Students will be able to calculate the force load in beams
- Students will be able to apply Euler's Equation to determine plate thickness
- Students will be able to use composition of functions in Excel to determine project costs

The Teaching Cycle:
Launch, Part 1:

Have students complete the Desmos Launch activity. In this activity, students will practice solving problems using ratios, and proportions. As part of the Desmos activity, students will view two different videos. The first video interviews steel fabrication workers to provide an in-depth look into the day-to-day job operations from a construction aspect. The second video interviews a local steel fabrication company, SteelFab Inc., to provide insight from the architectural perspective to explain the math and engineering elements that must be considered prior to construction. This video also provides some general information about the WTCC program and the possible careers the program can lead to. At the end of the Desmos Activity, students will be introduced to some terminology that they can expect to come across in the activity. For example, *Horizontal Beam, Vertical Beam, Diagonal Brace, Lateral Force, and Force in Diagonal Brace.*

Explore, Part 1:

Students will work in teams to complete questions 1 - 6. Teacher will circulate and monitor groups to ensure that they are making progress. For question 2, ensure students recognize the different braces and how to account for the two-way distribution of load in F1 (see discussion questions below to prompt students). Also, pay specific attention to their answers to questions 3 and 4, as it impacts their overall conclusion in future questions. As students are working on their calculations, look for groups that are using different rounding strategies to highlight during the 'Discuss' phase.

Discuss, Part 1:

Student teams provide solutions to question 2. Suggested questions to further discuss question 2.

- ❑ How did you find the missing information we needed in order to be able to compute the force in the diagonal brace?

  (Pythagorean theorem)

- ❑ How were your calculations for the F1 brace different from F3 and F2?

  (must divide horizontal length in half since the brace started in the center of the horizontal beam, as opposed to the top right vertex and divide the force kips in half)

Student teams recommend beam thicknesses. Suggested questions to further discuss questions 5 & 6.

- ❑ What about rounding? What did your team decide to do with the decimal answers? Did your method for rounding impact your final answers? If so, how?

  (did not impact overall answer because of the large range in thickness values from one increment to the next - decimals were negligent in the grand scheme of the problem)

- ❑ What if your compression force at a particular brace is 132 kips; would you recommend a beam thickness of 0.375 inches or 0.50 inches?

  (answers will vary - 0.375 because it is below the recommended threshold and SteelFab already accounts for a 2.0 safety factor, so there is already a cushion built-in. OR 0.50 because it is on the cusp of the recommended threshold and we would rather be safe than sorry)

Launch, Part 2:

This part of the lesson investigates how estimators working with the engineering firm provide consumers with a bid/budget for their desired project. Teacher will direct students to the "Estimating Costs" Excel template and the bulleted list of information written in Part 2 of the student worksheet.

Explore, Part 2:

Students will work in teams to complete the "Estimating Costs - Template" Excel spreadsheet. Teacher will circulate and monitor groups to ensure that they are using built-in formulas/commands/cell references to compute values.

Discuss, Part 2:

Have student teams report total cost. Allow groups to problem-solve if teams did not reach the same conclusion. Suggested questions to further discuss the spreadsheet and question 7.

- ❑ What values did we need to round and why?

  (Gallons of paint and truck loads, because neither of these values can be factions, only whole gallons and whole loads)

- ❑ Why is using Excel beneficial, as opposed to doing the computations by hand?

  (using cell references allows you to change one value and the other functions using that value automatically change)

- ❑ How could you use Excel to help you with Part 1 of the task?

  (create tables for force in beam equations, create table for various thicknesses and let Excel generate the various solutions to Euler's Equation)

Exit Ticket:

If $f(x) = x^2 + x - 2$, find f(5). Then take that value and evaluate $g(x) = 3x + 7$. What is the final answer? How is this problem similar to what we did in the "Loads of Steel" task?

Extension:
Students can design a physical model of the parking structure, using scale factors where possible. Students can research and create a formal bid proposal using information from the spreadsheet to present with the model.

Assessment:
Additional problems, recreating part 1, can be used for additional practice or assessment