Bridge Design Process
2025 NHERI Real-time Multi-directional Facility at Lehigh University
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- **Summary**
  Students will work in teams to design and build a bridge using K'NEX that spans a fixed gap (about 10–20 in). After construction, each bridge will be tested by hanging weights from the center to see which one holds the most weight before collapsing. The goal is to apply engineering and physics principles like force, tension, and compression, while also practicing teamwork and problem-solving.

- **Engineering Connection**
  This bridge-building activity connects to engineering by simulating the process engineers use when designing real-world structures. Students can learn about the engineering design process - planning, building, testing their bridges - while considering factors like material strength, load distribution, and structural stability. They will also learn about how forces such as tension (pulling forces), compression (squeezing forces), and shear (sliding forces) impact a structure.

- **Audience**
  Grade 6-8 students (middle school/junior high)

- **Lesson Objectives**
  - Understand the engineering design process: Plan, build, test, and refine a structure based on specific goals and constraints.
  - Identify forces: Recognize how tension, compression, and shear affect the strength and stability of a bridge.
  - Apply basic physics principles: Understand basic concepts of load distribution, trusses, and material properties.
  - Collaborate in teams: Work with peers to brainstorm ideas, assign roles, and solve problems together.
  - Reflect on designs: Evaluate bridge performance, identify weaknesses, and redesign to improve strength.

    - Develop critical thinking skills: Use trial and error to optimize design and learn from failures.

- **Educational Standards:** MS-ETS1-2 Engineering Design

MS-ETS1-2.

- Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

(Science and Engineering Practices)

- Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.
- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

(Disciplinary Core Ideas)

- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.

Common Core State Standards and Connections: ELA/Literacy

(RST.6-8.1)

- Cite specific textual evidence to support analysis of science and technical texts.

(RST.6-8.9)

- Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

(WHST.6-8.7)

- Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

(WHST.6-8.9)

- Draw evidence from informational texts to support analysis, reflection, and research.
- Reason abstractly and quantitatively.

(MP.27.EE.3)

- Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.

- **Material List**

- K'NEX building sets (1 per group)
- Weights (e.g., washers, small sandbags)
- String (for holding weights)
- Ruler or measuring tape (to measure span and dimensions)
- Stopwatch
- Paper for design drawings and recording data
- Pens/pencils

- **Introduction**
  The motivation for the lesson plan is to introduce the engineering design process and have students work through planning, building, and testing their bridges, then refining their design at the end of the activity through a quiz or discussion. Also, this lesson introduces students to the field of engineering and important engineering skills such as problem-solving, critical thinking, and reflection.

- **Procedure**
  - Background knowledge
    - Knowledge of trusses is the most important as they are the basis for the bridge structure and will provide supports that will have little learning curve to understand.
    - Familiarity with K'Nex helps to understand how pieces can be assembled and, thus, what structures can be created.
  - Before the activity
    - Have all K'Nex parts organized, which can be done two ways:
      - Hard mode – Organize all pieces by type in the middle of the room. Empty bins can be provided by students to make supply-carrying easier. Students will have to come to the center of the room to collect supplies.
        - Better suited for longer time periods
        - More complex resource scarcity and build process
      - Easy mode – Organize all pieces into preset kits for each group to have. These kits will have the same amount of the same parts per group.
        - Better suited for shorter time periods
        - Gives the student more time to focus on building
        - Less stressful version of resource scarcity and provides a common evaluation factor
    - A model bridge can be created to give students an idea of what their end goal should be and how they will be evaluated.
      - (OPTIONAL) Remove model after showing to prevent copying and encourage students to independently develop designs.

        - A slide presentation showing real-life examples or design tips to introduce the topic
        - Preselect groups or randomly assign groups
    - During the activity
        - Set a timer
        - Observe students and be readily available to assist them
        - When time is up, have each group come up one-by-one and have their bridge tested.
            - Do this by creating a gap between two support surfaces (i.e. between two tables) and hanging a predetermined weight from the middle of the bridge.
                - For more advanced versions, use multiple weights.
                - Keep this test the same for all groups
    - After the activity
        - Have each group fill out a short quiz that re-evaluates their bridge test results and design choice. (Basically, why it did or did not work.)
            - Or have a group discussion

- **Assessment**
  Their mastery will be known based on the performance of their bridge and how well they are able to conceptualize what they did and what occurred as a result.

- **Wrap-up**
  Closing discussion or written quiz that has them re-evaluate their design choice and subsequent results. Maybe have them connect it to a real-life example. Written quiz may be easier and less anxiety-inducing than the group discussion, and it will allow them to write down more questions they have on the subject, if any.

Educational Standard Source:

MS-ETS1-2 engineering design. MS-ETS1-2 Engineering Design | Next Generation Science Standards. (n.d.). https://www.nextgenscience.org/pe/ms-ets1-2-engineering-design