Optimizing Structures	Grade 5 Structures and Mechanisms

Lesson Plan

Coding Tool	Algorithms
Cross-curricular	N/A

Big Ideas

- We can measure forces in order to determine how they affect structures and mechanisms. This information can be used to guide the design of new structures and mechanisms.

Engineers are now using computer algorithms to generate structures that are lighter and stronger than ever before.

Specific Expectations

2.4 Use technological problem-solving skills to design, build, and test a frame/structure that will with-stand the application of an external force or a mechanical system that performs a specific function

Description

Students will create a structure (a tower or bridge) using 3D-doodle pens and follow a simplified generative design algorithm to strengthen it until it can support a load.

Materials

- "3D doodler" pens
- If "3D Doodlers" are not available: possible alternatives:
  - Paperclips and pieces of eraser
  - K'nex
  - Spaghetti and marshmallows

Computational Thinking Skills

- Algorithmic thinking
- Loops
- Conditional statements

Introduction

- Introduce, or re-introduce, the idea of an algorithm: a series of instructions in the form of specific, concrete steps. (You can link this to procedural writing, if desired.)
- Discuss the challenge of creating the lightest possible structure that can withstand a load. Introduce the type of structure you wish your students to build (for example, a bridge, or a tower for a wind turbine.)
- Discuss the idea of 'generative design'. In this type of design, a computer simulates the structure and adds material wherever it can to produce the lightest possible structure. (If the computer is removing material from an existing design to make it lighter, we call that 'topological optimization'; if the computer is starting from scratch, engineers call

that 'generative design'. We're going to be doing generative design.) A computer can run millions of simulations to do this test. Explain to your students that we're going to act like that computer simulation, using a similar algorithm by building and testing our structure in the real world.

Action

Have students build a single-string skeleton of the structure they intend to build using the 3D doodle pens. Make sure they are aware of the forces that they need to test with (weight, wind load if using, etc). Have them follow the 'structure generation' algorithm on the associated handout. Ensure they only increase the load by a tiny increment at once (a small coin at the most, or pieces of eraser) so as not to overload and collapse their structure. Remember that the higher the target load, the longer it will take to reach it!

The algorithm is reproduced here, for reference:

WHILE load is less than target load
    Add tiny weight
    IF any structural member deflects (bends)
    THEN
        Remove the weight and
        add material to or around that member

(In plain English: Have students add a tiny weight to the structure. If any part of it is seen to bend, they are to remove the weight and add more material to the weak area using the doodle pens. Then add weight, and check again. Repeat until the tower holds as much weight as the target load.)

Note: If you are using an alternative building tool, the algorithm may need to be modified as the structure may begin to break rather than bend! So instruct students to watch for that instead.

Consolidation/Extension

Start with just a weight load on your tower or bridge structure. Once the weight load has been accounted for, repeat with wind load using a variable-speed fan.

This is cutting edge engineering technology which may make some jobs obsolete (if the computer is doing the work, we need fewer engineers) -- you can invite your students to a discussion or writing project about the impact of this technology to society to help satisfy specific expectation 1.2

Assessment

If a scale is available, weigh each structure. The goal of this sort of evolutionary design is to produce the lightest possible structure, so weight can be used to assess their success in following the algorithm.

Additional Resources

Topological optimization :
https://www.caess.eu/site/Software-Animations.html
https://www.autodesk.com/solutions/topology-optimization

Generative Design:
https://www.engineering.com/DesignSoftware/DesignSoftwareArticles/ArticleID/20167/Generative-Design-Takes-on-the-Golden-Gate.aspx
https://www.autodesk.com/solutions/generative-design

3D Doodler:
https://learn.the3doodler.com/edu/
https://learn.the3doodler.com/lessons/stem-bridging-the-gap/