Berkeley Engineers and Mentors

Earthquake Challenge!

Lesson Type: Engineering Building Challenge
Target Grade: Elementary/Middle School
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Semester: Fall 2014

Foreword

This lesson is a little bit *different*; the goal here is to give students a challenge prompt, and nothing else. The students are expected to dive in and construct a solution from scratch. It is then the mentor's job to provide a lot of hands-on guidance as the students fail and iterate. The lesson is meant to be living, breathing, and moldable to your specific situations. Thus it is a lesson on how to solve a problem – so meta!

Brief Overview/Challenge

The purpose of this lesson is to explore building earthquake-proof structures. We delve into the foundation, building materials, and reinforcing techniques.

Teaching Goals

- Engineering Design Process – build, break, repeat
- Need to have a strong foundation to root your structure in
- Need to mix material types and philosophies (no one way to do it)
- Teamwork
- Iterate, iterate, iterate; redesigning from failure

Agenda

- **Brief Introduction** (10 min)
    - Purpose of the lesson: design earthquake safe structures
    - Types of earthquake waves
    - GENERAL ideas on how to approach

    - Introduce the challenge for this lesson
- **Build** (40 min)
    - Lay out and distribute the materials
- **Test** (5 min)
    - Test the students' designs
- **Recap** (10 min)
    - Go over what went well and what didn't go well for the building

Materials

- Materials can be found in the table, and are quite easy to produce except for the large amount of dirt, rocks, and Tupperware.
- Groups of 2-3 people. Each group gets:
    - 1 Tupperware container
    - 1 Strip of tape, 1~2ft (unlimited, but start with this amount)
    - 10 popsicle sticks & 10 straws (they can switch out later on)
    - Unlimited dirt, sand, rocks, marbles
    - Unlimited cardboard (but small amount)

Brief Introduction

Introduce that today is about designing structural sound buildings against earthquakes. Ask them what they know about earthquakes, if they've ever experienced them, what happens to buildings during. Keep it short, 5 minutes maximum. If you want you can go into different seismic waves:

- *P waves* are compression waves, fastest, move like slinky
- *S waves* are second fastest, move like when you shake a sheet or carpet by moving your arms vertically really quickly, only moves through solids
- *Surfaces waves* arrive after the above *body waves*, but cause the most damage; they can move side to side, or like ocean waves, and only travel through crust of the earth

Challenge

"Build a structure with a foundation, out of these materials and in any design you choose, to be strong enough to withstand a load and an earthquake."

- The weights will be rocks. They can tape the rocks on, but they should be attached to the tallest part of their structure to simulate top-heavy. To extend the challenge, see "Extending the Challenge" section.

Test the structure by simulating an earthquake. Have a mentor shake the Tupperware, start gently and work up until you can deem it stable or not. Stability means…

- The structure does not excessively shake or bend (*if the structure is vertical 90 degrees to the ground, it shouldn't go past around 95 or 100 degrees w.r.t. horizontal).*
- Stays upright while holding a reasonable amount of weight (rocks)
- Students can pretend there are people inside the building. Do you think the people inside would survive? What if there were objects inside that could fall off the walls or tip over? How much damage would there be?

Procedure

- Give each group a Tupperware. Offer them 10 popsicle sticks and 10 straws, and tell them they can swap them out for more of the other. Give them tape (unlimited, but start off with a set amount and advise them not to waste).
- Offer them dirt, rocks/marbles (have it up front). If you have a big site, you may have extra Tupperware/bags to hold dirt and rocks to prevent crowding
- Build, testing at each iteration (see **Testing:** below)
- Have a final demo at the end to show off each group's result

Some things to keep in mind:

- As the students struggle and tackle the problem, guide them with the teaching points in the next section.
- **Testing: When a group finishes an iteration** (they think they are 'done' and have a standing structure), put a rock (or two) on top of their structure and shake it to simulate an earthquake.
- If the structure fails, confront them about it and have a short but involved discussion about why and how to fix.
- Don't give them the solution right off the bat; have them address what the issue is, and *then* if they are unsure how to fix it then you can suggest it.
    - *Ex. Tower is tall, falls over during shaking. Don't just say "Hey, try crossbeams, like this." First, ask them which parts of the structure were weak, if certain parts were pulling apart or had most stress,, have them figure out they need to divert the stress/reinforce. Then, give them the crossbeam.*

Material to Teach

This is the real meat of the lesson. As you've given little explanation or background, the bulk of the teaching will come when you work with the students on their project. We want to ultimately guide them into reaching these

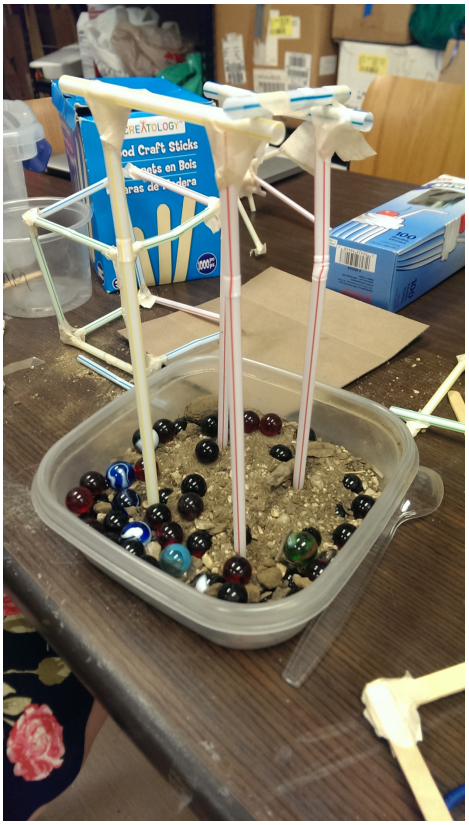
realizations, and incorporating them. However, be subtle, don't give them the answer straight up; the **Socratic Method** of *questioning* can be powerful here.

- **Squares vs Triangles**: build a square and triangle out of popsicle sticks and tape, and demonstrate to them that the square flexes, but the triangle is rigid.
    - Square's angles can be changed after construction
- **Foundation**: Mixing the dirt with the rocks gives an optimal mix of heaviness and rigidity to hold the fort down.
    - Make sure they create a base connecting the vertical walls, and then cover it with the dirt/rocks for best stability instead of just sticking it into the dirt.

It's stuck well in there!

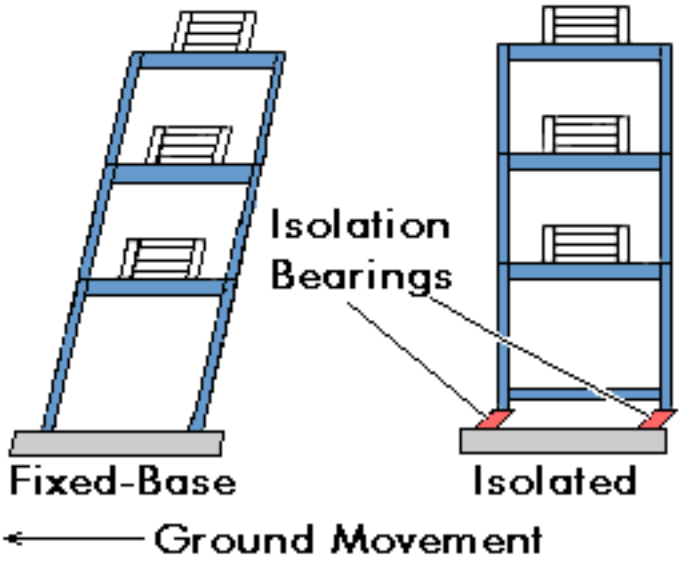
Connect the base for extra stability.

This will be very strong.



An example first iteration, might be weak.

- Modern practice is to raise the building from its base via a bed of flexible springs and cusions (see figure, could be hard but interesting!)



- **Wide Base:** A base wider than the top will be more stable, or supports can help.

- **Different Materials:** each materials has different properties and uses, when might a straw be better than popsicle stick and vice versa?
    - Real buildings have flex to counter earthquakes – consider if this does or doesn't work in our scenario.
- **Crossbeams** – connect corners and edges across a face; this distributes the load outwards to the strongest part of the structure, the skeleton.

Extending the Lesson

Once they have a structure that holds a weight through shaking, challenge them to accomplish these:

- Tallest building
- Holds the most weight
- Least shaking – they now can't tape the rocks to the top, but must place the rocks on a piece of cardboard. A mentor will reasonably shake it and see if the rocks fall off
- "Flood" the structure by pouring water into the foundation, then induce shaking – does it hold? (*Note: there may not be a right answer for how to fix this, it's more hypothetical and exploratory.)* How did the water affect the stability?

References

https://www.teachengineering.org/view_activity.php?url=http://www.teachengineering.org/collection/cub_/activities/cub_natdis/cub_natdis_lesson03_activity1.xml

http://www.pbs.org/wgbh/nova/education/activities/2302_shook.html

Summary Materials Table

- For Logistics' convenience, have a summary materials table for each modules at the very end of the lesson on a separate page
- Make sure to include a vendor link or picture to ensure that logistics buys exactly what you want

Material	**Amount per Group**	**Expected $$**	**Vendor (or online link)**
Popsicle sticks & Straws	20 total combined	$10/box	
Tape	2,3, or 4 rolls per site		

	depend on size		
Tupperware, square sandwich size	1		
Cardboard	1 piece medium sized		

Additionally, to cover all the sites you will need one **BIG** bag of dirt and another **BIG** bag of rocks (for those following along at home, each person performing the activity will want to fill up their tupperware with these, so acquire that much).

Conclusion

Remember, this lesson isn't about a single science, but rather using a breadth of knowledge. We don't go too in-depth about earthquakes or structural supports, nor is it the goal to imprint on them such facts. The goal of the lesson is for them to learn *how to solve a problem*. The students are:

1. Given a challenge to accomplish, with little background or guidance (as real life problems often are presented)
2. Asked to design, build, *FAIL*, struggle, redesign, and iterate.

The whole purpose of giving little guidance is for them to **figure it out on their own**, or at least reasonably attempt it before getting hints. Don't straight up tell them, but guide them in explaining. This is just as much a lesson for you as a mentor. It's an easy lesson with endless opportunities to expand, go with it as you will.

Best,
Jerry Lung