Lesson Title: STEM Earthquake Engineering Design Project: *Design a building that can withstand an earthquake.*

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Topic: How is the Engineering Design Process used to solve a real-world problem such as designing a building that can withstand an earthquake?

Targeted Grade Level: High School Earth Science Grades 9-10

Time Needed: 6-10, 43-minute class periods.

Subject Integration: This lesson integrates several categories of STEM, but the focus is on Science and Engineering. Literacy will also be integrated through reading and research about the history and development of earthquake resistant buildings.

Justification:

This project lends itself well to STEM integration. Designing a building that can withstand an earthquake requires students to understand what causes earthquakes, how to triangulate earthquakes, and earthquake preparation and safety, which they learn about in their earth science class. Thinking about designing a building to withstand an earthquake allows students to participate in the engineering design process in a meaningful, real-world scenario. They can sketch and modify their model designs as well as use the designated building blocks to build a design a model building that will be tested on a quake shake table. This process helps students connect their knowledge of earthquakes to finding a solution to a real-world problem, developing earthquake resistant buildings for locations prone to regular earthquake activity. By asking students to prepare a rationale, or final report to try to persuade a company to choose their design, students are learning the importance of communication and literacy across all curricula. Being able to clearly communicate, through writing, is an important professional skill that they will require no matter what career path they choose.

STEM integration makes the most sense for a project like this because it taps into areas of science, technology, engineering, and mathematics of various levels throughout the activities. It is a great way to approach the introduction of each of these areas into the classroom for those of us beginning the transition to the new standards.

S- Earth Science (NYSSLS standards pgs. 28-29, see link in 5E lesson below)

HS-ESS3-1: Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

HS-ESS3-3: Create a computational simulation to illustrate the relationships among Earth's systems and how they interact.

T- Use of the internet for research, use of CAD or Google SketchUp (for students in College Link engineering or P-Tech program), Use of Microsoft Excel and Word, using smartphone Apps to determine the seismic equivalent of each setting on the shake table.

E- (NYSSLS standards pg. 30, see link in 5E lesson below)

HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

M- Calculating the budget for the building design.

ELA/Literacy Integration- Students will read an article called “Earthquake safe structures” in addition to articles they find during their own research. Students will write a proposal for their building design, including a Claim-Evidence-Reasoning explanation/justification for their design, in accordance with ELA NGSS standard:

9-10.WHST.2 Write informative/explanatory text focused on discipline-specific content. (HS-ESS3-1)

Standards:

NGSS Performance Expectations: SEE NYSSLS pgs. 28-30

HS. Human sustainability

HS-ESS3-1 Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

HS- ESS3-3 Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.

NYSSLS PDF LINK-

https://www.nysed.gov/sites/default/files/programs/curriculum-instruction/hs-science-learning-standards.pdf

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories. ▪ Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-ESS3-1)	**ESS3.B: Natural Hazards** ▪ Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations. (HS-ESS3-1)	**Cause and Effect** ▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS3-1) **Stability and Change** ▪ Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS3-3)

		Connections to Engineering, Technology, and Applications of Science **Influence of Engineering, Technology, and Science on Society and the Natural World** ▪ Modern civilization depends on major technological systems. (HS-ESS3-1),(HS-ESS3-3)

New York State Next Generation Learning Standards:

ELA/Literacy:

9-10.WHST.2	Write informative/explanatory text focused on discipline-specific content. (HS-ESS3-1)

Mathematics:

MP.2	Reason abstractly and quantitatively. (HS-ESS3-1),(HS-ESS3-2),(HS-ESS3-3),(HS-ESS3-4),(HS-ESS3-6)
AI-N.Q.3	Choose a level of accuracy appropriate to limitations on measurement and context when reporting quantities. (HS-ESS3-1),(HS-ESS3-4),(HS-ESS3-6)

ITEEA Standards *N/A*

Other Standards

HS. Engineering Design

HS-ETS1-2. **Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.**

HS-ETS1-3. **Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.**

Measurable Student Learning Objectives:

SWBAT:

- Use the Engineering Design Process and knowledge of earthquakes to design a building to create a model building that can withstand an earthquake.
- Work collaboratively to create a written proposal promoting the building design, integrating CER into their proposal.
- Peer review and provide constructive feedback on other building designs.
- Calculate the budget for building materials and provide justification for going either over budget (if applicable).
- Analyze real-time earthquake data to include CER in final building design proposal justifying their choice for design based on the quake shake magnitude they chose to use for their experimentation.

Nature of STEM:

Science- this lesson requires students to use their knowledge of earthquakes to help solve a real-world problem.

Technology- students will use technology to research earthquakes and earthquakes resistant buildings. They will use shaking tables and building blocks to test their building designs. As an extension, students can also create interactive design proposals to accompany their written proposals.

Engineering- going through the engineering design process throughout the project will help students understand that engineering is about developing a solution to a problem by doing research, making models on paper and then in 3D.

Math- students are given design specifications and a budget and are asked to design within those constraints and if they deviate, they must justify their reasoning for doing so by providing evidence from their research.

Engaging Context/Phenomena:

Since this project is a multi-day activity, there could potentially be several engaging phenomena. As an anchor phenomenon, I would refer to this Building Sway video clip so that students can see that an earthquake causes large buildings to move rather dramatically due to the shaking of the earth beneath.
https://www.youtube.com/watch?v=2t2xxKMN-Ic&t=22s

YouTube video: What is LA's most Earthquake proof building? https://www.youtube.com/watch?v=iZoHoPFHAtw&t=27s

Top 5 Earthquake resistant Structures From Around the world

https://interestingengineering.com/lists/top-5-earthquake-resistant-structures-around-world

Taipei 101 https://www.youtube.com/watch?v=CSyJBh8BB44

Building Sway https://www.youtube.com/watch?v=2t2xxKMN-Ic&t=22s

Data Integration:

Students will analyze data for CA earthquakes to determine how often they occur near LA and get a general idea of their average magnitude. As a team, they can then determine which amount of shake (Levels 1-5) from the Quake Shake table their model building should be able to withstand. They will use this data to make a Claim-Evidence-Reasoning (CER) argument as part of their final proposal to justify their structure begin the best choice for CA.

I will provide multiple links for students to complete their research and data analysis, however, I like this site because it allows students to filter out earthquakes by magnitude, which would allow them to determine the average magnitude of earthquakes around the LA area and make a better choice for their Quake Shake settings.

http://ds.iris.edu/ieb/index.html?format=text&nodata=404&starttime=1970-01-01&endtime=2025-01-01&minmag=0&maxmag=10&mindepth=0&maxdepth=900&orderby=time-desc&src=usgs&limit=1000&maxlat=75.80&minlat=-75.80&maxlon=180.00&minlon=-180.00&zm=3&mt=ter

Differentiation of Instruction:

- Provide the student materials in both English and Spanish
- Adjust pacing for each class based on student need.
- Provide enrichment extension for advanced students (use of CAD and/or Google SketchUp)
- Student Proposal/Rational can be modified. Rather than a full, written proposal, students can write a summary and include a digital presentation to support their work.
- A digital proposal can also be done in addition to a full, written proposal, as an enrichment extension to the project
- Teacher may choose to create student groups to mix students of all learning dynamics.
- Teachers may assign individual tasks for team members, such as team leader, note taker, etc. to ensure all students are participating.

Real-life Connection:

Recently, there have been a few small magnitude earthquakes on the east coast, that some students felt. It led to questions about earthquakes in our area and a conversation about earthquakes in other countries. Many students in my classes are from other countries that experience more earthquakes, such as Haiti. Students share the experiences of their families who live in tectonically active areas outside of the United States. This also leads to a discussion about engineering design and how more economically and technologically advanced first world countries, like the US, have better infrastructure than countries like Haiti, which is why our buildings are better able to withstand earthquakes.

Possible Misconceptions:

One misconception that I have noticed recently is that students tend to believe that earthquakes ONLY occur at tectonic plates when they do in fact, occur elsewhere, but less often and typically at a much lower magnitude. One Regents question that may lead to this misconception is the typical "Why does California have more earthquakes than New York?" type question.

Lesson Procedure:

5E Model	5E Objectives
Engage (Day 1) *Introduce the lesson with an anchoring phenomenon. Facilitate student questions, discussion, etc. as appropriate. Learn about what students already know and want to know.*	**Procedure:** The teacher will place students into groups of 4. The teacher will play the Anchor Phenomena Video, Building Sway (see link in Resources below). Student groups will be given 2 minutes to discuss the video and brainstorm their ideas of the cause of the building sway. One volunteer from each group will share their ideas with the class. The teacher will post these ideas on the board. The teacher will hand out the Quake Shake blocks to each group. Students will remove the blocks from the bag, make observations about their sizes and shapes and organize them on their desks. Students will be asked to observe the differences between these blocks and Leogo's (these blocks do not lock together). The teacher will prompt students to use ALL blocks provided to create a building in the time allotted. When students are finished, they will be instructed to carefully take a short gallery walk around the classroom to observe each other's buildings. The teacher will take a picture of each building so that they can be referenced later if needed and so that any absent students can view them in the future. Students will then be asked to write down quietly and independently one feature from any building that they liked the best and one feature from any building that they would suggest modifying and why. **Modifications:** The time designated for each activity may be adjusted to meet the needs of students. ENL students will receive the directions in both English and Spanish (or other primary language) ENL students will also be permitted to use Google Translate or another translation App as needed and speak with other bilingual students for clarification as needed. **Standards Addressed:** N/A

	Formative/Summative Assessments: Teacher will assess student engagement by observing each group, taking pictures of their buildings, and checking their responses to questions in their notebooks. **Resources** *Anchor Phenomenon: Building Sway Video* https://www.youtube.com/watch?v=2t2xxKMN-Ic&t=22s Student Packet- attached. Quake Shake Blocks- images of blocks are on pg. 1 of student packet.
Explore (Day 1-2) *Plan for students to engage in hands-on activities that are designed to facilitate conceptual change.*	**Procedure:** The teacher will pull up images from Gateway of Astronaut Photography of Earth (link in Resources below) to show students ariel views of areas in the US that have experienced earthquakes, noting that when an earthquake happens in an unpopulated area, it is difficult to see the effects of the seismic waves. However, when viewing a populated area, such as a city, the effects of earthquakes are very clear in pre- and post-quake imagery. Students will be asked to think-pair-share with a partner: Why are some areas of the world more prone to earthquakes? Why do some earthquakes cause more damage than others? How does engineering play a role in the effects seismic waves have on city buildings? The teacher will choose several students to share and summarize their discussion with the class. Students will write their name, and the names of their teammates on each student packet. The teacher will read the assignment prompt (student packet pg.1) out loud, twice. First, students will listen to the prompt. During the second reading, students will be asked to write down any questions or concerns they might have. As a group, students will discuss their questions and concerns to create a few questions to pose to the class and teacher. One volunteer from each group will share their group question with the class. Other students will be given the opportunity to respond to the question before the teacher responds/clarifies. (10 minutes) The teacher will ask each group to re-read the assignment prompt on student packet pg. 1 and continue reading student packet pgs. 2-3 which is a template for the engineering design process.

	The teacher will ask students to work together for the remainder of class to begin brainstorming their ideas for a build design that meets the requirements outlined in the prompt. Students may sketch, discuss, do internet research, and use the Quake Shake blocks during their brainstorming session. Students will also be provided with a list of real-time earthquake data websites to use as part of their research (Separate attachment) Students are encouraged to take note, makes sketches, and take pictures of their brainstorming builds so that they can start from here again tomorrow. (For the reminder of class) Continued DAY 2- Students will gather their materials and sit in their groups. The teacher will present some real-time earthquake data, focusing on California. Students will have a chance to ask questions and the teacher will review the Explore task from yesterday. Today, the teacher will go over student packet pgs. 2,3, and 5 which students will begin to fill-in as they continue explore ideas for their building designs. The teacher will circulate the room and assist as needed. **Modifications** The time designated for each activity may be adjusted to meet the needs of students. ENL students will receive the directions in both English and Spanish (or other native language) ENL students will also be permitted to use Google Translate or another translation App as needed and speak with other bilingual students for clarification as needed. **Standards Addressed** HS-ESS3-1 **Formative/Summative Assessments** Teacher will circulate the room and ask questions about each design. The teacher will check student packets to ensure each student is completing the work. **Resources:** Student Packet Quake Shake Blocks- images of blocks are on pg. 1 of student packet. Laptops Rulers Extra graph paper for sketches

	Earthquake real-time data websites- will be uploaded to assignment separately. Astronaut Photography Query page- https://eol.jsc.nasa.gov/SearchPhotos/ShowQueryResults-Table.pl?results=1689259079120722 Specific image links- https://eol.jsc.nasa.gov/SearchPhotos/photo.pl?mission=ISS021&roll=E&frame=8800 https://eol.jsc.nasa.gov/SearchPhotos/photo.pl?mission=ISS017&roll=E&frame=21862 https://eol.jsc.nasa.gov/SearchPhotos/photo.pl?mission=ISS011&roll=E&frame=13277 Pre-Post Imagery links https://disasterscharter.org/image/journal/article.jpg?img_id=18943135&t=1676884629422 https://disasterscharter.org/image/journal/article.jpg?img_id=18947883&t=1676896746014 https://disasterscharter.org/image/journal/article.jpg?img_id=20786564&t=1684841558393
Explain (Day 3) *Facilitate opportunities for students to explain their understanding of concepts and processes and make sense of new concepts.*	**Procedure:** Students will gather their materials and sit in their groups. The teacher will show the video, *What is LA's most Earthquake proof building?* https://www.youtube.com/watch?v=iZoHoPFHAtw&t=27s Students will continue their research by determining the average earthquake magnitude for the LA area using the Interactive Earthquake Browser from EarthScope (link below) or from any of the real-time earthquake data links they have been given. It is up to their team to determine, based on this data and the Quake Shake Table magnitudes, the maximum shaking they will attempt to design their building to withstand. They will have to justify their choice in their final rationale. The teacher will Explain how the Quake Shake table works during a classroom demo. The teacher will ask students to share their research so that as a class, we can determine what average magnitude earthquake is most common around LA. We will then brainstorm ideas as to how we

	can determine the Quake Shake table settings (1-5) might be equivalent to real-world earthquake magnitudes. Once we agree upon a method for testing this, we will do it as a whole class demo. The teacher will use a seismic wave App on her phone to identify the amount of shake each setting on the shake table equates to in actual magnitude. Screenshots will be shared with the class and the data table on pg. 4 of the student packet will be completed with this information. Student groups will now be given the Quake Shake tables; however, they will not yet be given the batteries. Today, they will use the table to ensure the dimensions of their buildings meet the prompt criteria and will continue their research and design sketches. They should now be completing pgs. -5 of their student packets during class. Student groups will have the opportunity to build their most recent design on the shake table and explain to the class the current pros and cons of their design. Others will have the opportunity to ask questions, share ideas and give constructive feedback about designs. **Modifications:** The time designated for each activity may be adjusted to meet the needs of students. ENL students will receive the directions in both English and Spanish (or other native language) ENL students will also be permitted to use Google Translate or another translation App as needed and speak with other bilingual students for clarification as needed. Pictures of the data from the seismic wave App can be found on pg. 4 of the student packet so that anyone who was absent during the actual demo and data collection can complete this later. **Standards Addressed** HS-ESS3-1, HS-ESS3-3, HS-ETS1-2, HS-ETS1-3 **Formative/Summative Assessments** Students share their designs with the class and explain what they like about it and what needs improving based on their research. **Resources:** Student Packet Quake Shake Blocks- images of blocks are on pg. 1 of student packet Laptops Rulers

	Extra graph paper for sketches Teacher cell phone, cell phone case with double sided sticky tape, seismic wave detector App Quake Shake table w/ 4 AA batteries (for teacher) Quake Shake table (no batteries yet) for student groups. Earthquake real-time data websites EarthScope link- http://ds.iris.edu/ieb/index.html?format=text&nodata=404&starttime=1970-01-01&endtime=2025-01-01&minmag=0&maxmag=10&mindepth=0&maxdepth=900&orderby=time-desc&src=usgs&limit=1000&maxlat=51.12&minlat=-51.12&maxlon=110.65&minlon=-110.65&zm=3&mt=ter
Elaborate(Days 4-7) *Provide applications of concepts and opportunities to challenge and deep ideas; build on or extend understanding and skills.*	**Procedure:** Students will watch the video, *Taipei 101* https://www.youtube.com/watch?v=CSyJBh8BB44 Students will log-on to their Actively Learn accounts to complete the Earthquake Safe Structures assignment (scanned copy will be attached separately). The assignment prompt asks students to '*think about… how can we build and fix buildings to make them safe during earthquakes?'* Paying special attention to design aesthetics, environmentally friendly features, and cost. Students will work on their design, with a focus on aesthetics and cost in mind. Students must calculate the cost of their building and determine if they are over or under budget in accordance with the assignment prompt, and make modifications as needed. Students will test their building models on the Quake Shake tables and continue to revise their models until they are satisfied that the building model adequately satisfies the project prompt requirements. **Modifications:** The time designated for each activity may be adjusted to meet the needs of students. ENL students will receive the directions in both English and Spanish (or other native

	language) ENL students will also be permitted to use Google Translate or another translation App as needed and speak with other bilingual students for clarification as needed. Hard Copies of the Actively Learn assignment will be available for any student having difficulty logging into their account. Translated hard copies will also be made available for ENL students. **Standards Addressed** **Formative/Summative Assessments:** Actively Learn Assignment **Resources:** Student Packet Quake Shake Blocks- images of blocks are on pg. 1 of student packet. Laptops Rulers Extra graph paper for sketches Quake Shake table w/ 4 AA batteries. Actively Learn Assignment
Evaluate (Days 6-8) *Assess students' knowledge, skills, and abilities.*	**Procedure:** Students will peer review another group's building design using the peer evaluation form on pg. 7 of the student packet. Students will then finalize their proposal and rationale, including a CER about their choices related to any modifications they made to the RFP building specifications and/or the agreed upon magnitude the class agreed upon. Students will practice their sales pitch promoting their building design and prepare to present to the class before Quake Shaking their building for the class to observe. **Modifications:** The time designated for each activity may be adjusted to meet the needs of students. ENL students will receive the directions in both English and Spanish (or other native

	language) ENL students will also be permitted to use Google Translate or another translation App as needed and speak with other bilingual students for clarification as needed. Students may choose to provide a shorter written summary accompanied by a brief slide deck as part of their sales pitch. **Standards Addressed:** HS-ESS3-1, HS-ESS3-3, HS-ETS1-2, HS-ETS1-3, ELA 9-10.WHST.2, Math MP.2, Math AI-N.Q.3 **Formative/Summative Assessments:** The teacher will grade the Regents Practice Questions, student packet pgs. 8-9 The teacher will use the project grading rubric found on pg. 10 of the student packet to evaluate the overall performance of each individual student. **Resources:** Student Packet Quake Shake Blocks- images of blocks are on pg. 1 of student packet. Laptops Rulers Extra graph paper for sketches Quake Shake table w/ 4 AA batteries

Teacher Background:

The teacher must have knowledge of the NYSSLS standards and Regents Earth Science curriculum. Curriculum content pertaining to earthquakes should be taught prior to the start of this project, so that the major focus for students is on the engineering design process rather than learning background information related to earthquakes.

Below is an image of the quake shake tables I purchased for this project (It was $19.99 at the time and I purchased six, along with the requisite number of AA batteries) They can be found at https://www.lakeshorelearning.com/search/products/page-1/sort-best/num-96/loc-031?view=grid&Ntt=earthquake

However, there are several other options in school supply stores, Amazon, Target, Walmart, etc. that may be more appropriate for other teachers/schools. Additionally, an extension to this project could be for students to design their own shake tables. The exact blocks and shake table used in this lesson are not required. The lesson can be modified to use whatever supplies are available to you.

Survive the Quake Engineering Kit
$31.99
reg. $39.99
★★★★★ (69)