Move and Shake: A Hands-on Activity Connecting Engineering to the Everyday World for Secondary Students

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Abstract

One of the main goals of Project STEP (Science and Technology Enhancement Program) is to design, develop, and implement hands-on activities and technology-driven inquiry-based projects, which relate to the students' community issues, as vehicles to authentically teach science, mathematics, engineering and technology skills. The Movers and Shakers Lesson Plan was a three-part activity that helped students connect engineering principles to the design of buildings that resist earthquake damage. This paper describes the objectives of the lesson and how the activities related to those objectives. Pre- and post-assessments were completed to measure the impact of the lesson on students learning. Overall, seventh grade students showed a significant improvement in their scores when tested on the specific concepts of plate tectonics. The use of a grading rubric to assess the students' projects showed that students mastered the concepts taught. Students were also surveyed about their perceptions of the lesson and its impact on their learning and attitudes towards science. 71% said the lesson increased their interest in engineering, 86% said they learned "a lot" from the lesson and 72% reported some increase in their confidence about being able to learn math and science. Reflections of the engineering students responsible for implementing the activity are also discussed.

Background

Project STEP (Science and Technology Program) is a joint effort between the Colleges of Engineering and Education at the University of Cincinnati to partner with schools in the Cincinnati Public School system. Project STEP connects engineering graduate students with middle and high school science educators to help bring authentic learning activities into the classroom. The project is funded through the NSF GK12 program to enhance science education. Over the course of the three year program, STEP has involved 16 graduate and 8 undergraduate fellows working with 33 teachers distributed throughout 7 schools in the Cincinnati area. Fellows and teachers have implemented over 20 different activities in classes covering physics, math, biology, chemistry and environmental science. These activities involve authentic, inquiry based learning and details are available at the project website. (For further information please see http://www.eng.uc.edu/STEP/overview.)

The Lesson

The Movers and Shakers lesson was designed for a seventh grade general science class and occurred as part of a unit in plate tectonics; however, it was primarily directed towards the destructive effects and prevention strategies associated with earthquakes. The lesson took place over six days, each 60 minutes in length.

The previous unit that the students had covered in class dealt with the concept of waves; therefore, they were already familiar with terms such as "frequency" and "amplitude." This made it much easier introduce concepts such as natural frequency, resonance, and damping. The specific objectives of the lesson were that students would be able to:

1. define the above vocabulary words and have a general understanding of the scientific concepts.
2. describe an earthquake in terms of frequencies.
3. identify the natural frequency of an object.
4. understand what determines the natural frequency of an object.
5. explain how and why earthquakes are destructive.
6. contribute ideas to the design of a building that is meant to withstand an earthquake.
7. have some knowledge of specific historical earthquakes.

In the first part of this lesson, through the strumming of a guitar, the students were introduced to the concepts of frequency, amplitude, acceleration, stiffness, resonance, natural frequency, and damping. They then participated in several exploratory activities that illustrate those concepts in a hands-on atmosphere such as using rubber bands and simple structure setups made from wood, metal wiring and fun ball.

The second part of the lesson was a one hour movie about one particularly destructive earthquake that took place in northern California. This was meant to illustrate the reality of the situation to students. During this time the students followed along with a worksheet which had questions relating to the different sections of the movie.

In part three, they were taught about the effects that earthquakes have on buildings by simulating the event on a shake table. The students made observations about the impact of changing variables of stiffness and mass. They also discussed some of the basic design techniques that civil engineers use to help them to sustain such forces.

Last, students built their own structures from a variety of materials designed to stand up to an earthquake. They also had the opportunity to get a closer look at the shake table, how it works, and how this information might possibly change their design. The materials were not limited to any certain amount, but the dimensions of the structure had to fit within a certain size. The students then tested their buildings on the shake table and completed feedback forms indicating the results.

A key element of this lesson was that it was related to the field of engineering. These students had spent the previous week studying the science of plate tectonics. They had learned about the causes of earthquakes, and this lesson was designed to help them consider the effects. Civil engineers design buildings with an understanding that there is always a risk of an earthquake. In certain parts of the world, that risk is greater than others, but still, precautions are always taken during the design process. In order to better understand the logic behind this engineering design process, the students must first realize how and why earthquakes are so destructive (natural frequency and resonance); they can then learn how other scientific concepts (damping and conservation of energy) can be used to counter act those effects.

The Standards Related to this Lesson

The Ohio Standards of Science and Technology related to this lesson were as follows:

EARTH and SPACE SCIENCES: Grades 6-8

- Describe the processes that contribute to the continuous changing of the Earth's surface (e.g. earthquakes, volcanic eruptions, erosion, mounting building)

PHYSICAL SCIENCES

- Demonstrate that waves transfer energy.
- Demonstrate that vibrations in materials may produce waves that spread away from the source in all directions (e.g. earthquakes).
- Use historic examples to explain how new ideas are limited by the context in which they are conceived; are often initially rejected by the scientific establishment; sometimes spring from unexpected findings; and usually grow slowly through contributions from many different investigators (e.g. plate tectonics theory)
- Demonstrate that waves (e.g. sound, seismic, and light) have energy and waves can transfer energy when they interact with each other.
- Describe how the change in the position of an object is always judged and described in comparison to a reference point.

SCIENCE and TECHNOLOGY: Grades 6-8

- Give examples of how technological advances, influenced by scientific knowledge, affect the quality of life.
- Design a solution of product taking into account needs and constraints (cost, time, tradeoffs, etc.

The movie covered most of the standards in a visual manner, one which really made an impact because of the live movie clips taken of individuals there during the quake in San Francisco which personalized the experience. This movie was shown early in the week, after some initial background was given. Following the movie, a problem was posed in which the students used their learning to develop their best idea into a solution. Subsequent testing and feedback showed that their designs incorporated some of the concepts from the first two days.

Assessment of Student Learning

Approximately 110 students, in four classes, participated in the lesson. A seven-item pre-assessment questionnaire was given to all students to determine how much of the terminology related to the lesson was already understood (see Appendix A). A post-assessment quiz was given, as part of the students' midterm, to determine how much of the terminology they had learned (see Appendix B). Table 1 shows the results of the assessments which indicate that students learned a substantial amount of information as a result of the lesson. Overall, learning raised an average of 21% from pre- to post-test. Increases were found for six of seven concepts. An explanation for why the concept of damping resulted in decreases in learning is not clear. One possibility is that this concept is most often taught in college physics classes and that understanding of the concept exceeded the cognitive levels of the students. Another possibility is that the concept was not taught as well as the other concepts.

Table 1 Percent Correct on Pre- and Post-Test Assessments

	Terminology Known	Pre-Assessment	Post-Assessment	Amount of Change
1	frequency	17%	42%	+25%
2	resonance	8%	42%	+34%
3	amplitude	25%	33%	+8%
4	acceleration	38%	75%	+37%
5	stiffness	50%	92%	+42%
6	damping	63%	54%	-9%
7	natural frequency	46%	58%	+12%

Additionally students worked in groups to construct structures and test them out using the shake table. Students were assessed by groups on their oral explanation of their design prior to testing, the structure itself, and the foundations using the grading rubric shown in Appendix C.

Assessment of Student Perceptions of the Lesson

Students completed a survey at the end of the sixth day to evaluate the impact of the lesson on their own learning as well as their overall enjoyment of the lesson and its impact on their attitudes towards science. The results, indicated in Table 2, showed that students felt they learned a lot, and that it increased their interest in engineering, and helped them feel more confident about their ability to learn math and science.

Table 2 Student Perceptions of Learning and Interest

	Very interested	Somewhat interested	Not sure	No interest at all
How would you rate your interest in the field of engineering?	41%	35%	18%	6%

	a lot	a little	nothing new	
How would you rate your level of learning today?	86%	14%	0%	
	Increased my Interest	Decreased my Interest	Did not affect my Interest	
Did this program affect your interest in engineering in any way?	71%	5%	18%	
	Definitely	Sort of	Not Sure	No
Did this program make you feel more confident about your ability to learn math and science?	48%	24%	28%	0%

In addition, students were asked two open ended questions about what they liked most and least about the lesson and its related activities. Their comments reflected that they enjoyed the hands-on activities such as using the shake table and building their own structures. Students described the activities as interesting, exciting and fun and said they had learned a lot. They also commented that they liked least the part of the activity which required them to plan with others or to write, citing this as being boring.

Fellow Reflections

There were two fellows who helped to create and execute this lesson, one a senior level undergraduate, the other a Masters level graduate engineering student. Each fellow wrote a reflection regarding their perception of how the lesson went.

One fellow, an undergraduate in electrical engineering, reflected that the lesson was very successful with the classroom teacher providing extra time when the lesson was a little longer than anticipated. While a conceptually designed lesson, it could be easily adapted for higher grade levels by involving mathematics. Having students design and build their own structures really added to the engineering experience with students being extremely intrigued by the shake table. "In the end, this lesson seemed to be a great extension to [the classroom teacher's] plate tectonics unit. The material even made up a good portion of the student's midterm exam."

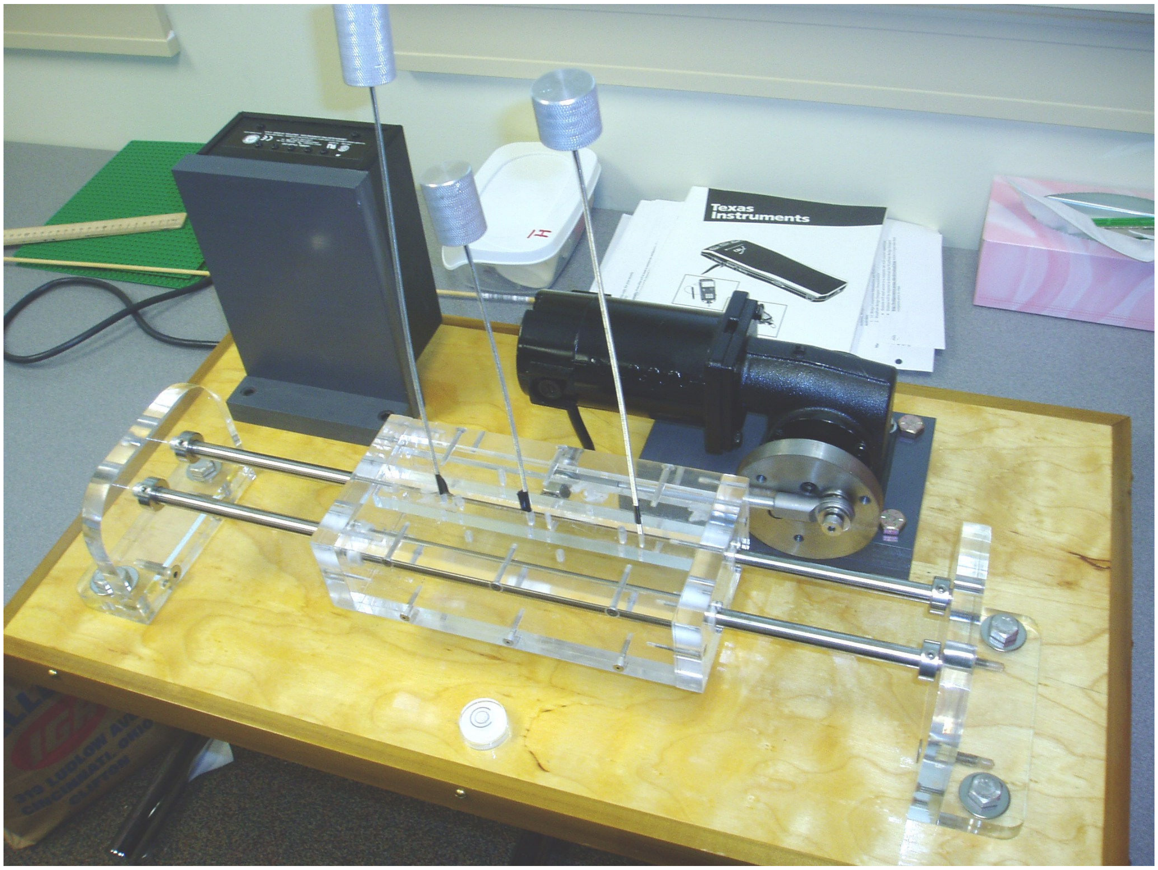
The other fellow, a graduate student in electrical engineering, reflected that the longer time that was needed happened because multi-tasking was taking place. "Although the use of the shake table may take some more time on the part of the delivering teacher in future years I still would recommend this since this really captured the students' attention and imagination."

Additionally, a module checklist (shown in Appendix D) was completed by the undergraduate fellow in which the lesson activities were reviewed and found to be aligned with science and technology standards, with content that was accurate, promoting student understanding in an interesting way that required their active participation, discussion, reflection, and requiring them to reach high levels of thought processes. Additionally, the activities were deemed innovative, framed within real life situations employing an engineering related concept, technology, and appropriately assessed.

Pictures taken during the lesson which correspond to the six days of activities are available through a web site indicated in Appendix E as well as the online links used for teaching the lesson.

In conclusion, students in this 7th grade general science class learned about earthquakes, volcanoes, fault lines and other topics surrounding plate tectonics. The goal was to help the students better understand some of the terminology and how scientists and engineers use knowledge from the way past earthquakes work in designing better buildings and structures which can withstand greater ground motion. The Movers and Shakers Lesson Plan successfully helped students connect engineering principles to the design of buildings that resist earthquake damage. Improvement in the students' test scores and assessment of students' projects showed that students mastered the concepts taught. Additionally, students had positive perceptions of the lesson and believed that the lesson positively impacted their interest in engineering and their confidence towards learning math and science.

SHAKE TABLE
DESCRIPTION



Above you will see the shake table we used in our case. This was custom built for the use in a college atmosphere, so it cost a little bit more then what can be used to make one of these. In general, there are 3 main parts to this setup:

1) The motor (right black box)
2) The controller (left black box)
3) The medium which oscillates (the plastic box on the 2 metal rods)

A more general description of what a shake table is and how you can make one using a handy power drill can be found here:

http://www.jclahr.com/science/earth_science/shake/

How it works in general is once the controller is plugged in there is a knob on the opposite side that controls the motor to the right of it and how fast the motor runs. The faster the motor runs, the faster the plastic box oscillates and the buildings screwed in to it. Also included in this zip folder attachment were a series of movies that can further explain how a shake table works and how it can be used to explain the concepts we wish to address in this activity. Other videos also include some of the testing in action as well as some of the activities throughout the week's lesson.

For more information please contact Dr Kukreti of University of Cincinnati's Civil Engineering Dept at anant.kukreti@uc.edu

Appendix A

Plate Tectonics Pre-Assessment Quiz

Note: Answers are indicated in bold

Directions: Please pick the correct term for the following definitions to the best of your knowledge.

1) The number of complete cycles of a periodic process occurring per unit time
   - A) Amplitude
   - B) Acceleration
   - C) Damping
   - **D) Frequency**
2) Intensification and prolongation of sound, especially of a musical tone
   - **A) Resonance**
   - B) Amplitude
   - C) Stiffness
   - D) Frequency
3) The maximum absolute value of a periodic curve measured along its vertical axis
   - A) Stiffness
   - **B) Amplitude**
   - C) Damping
   - D) Natural Frequency
4) The rate of change of velocity with respect to time.
   - A) Resonance
   - B) Amplitude
   - **C) Acceleration**
   - D) Frequency
5) Difficult to bend; rigid.
   - **A) Stiffness**
   - B) Damping
   - C) Natural Frequency
   - D) Resonance
6) To decrease the amplitude of (an oscillating system).
   - A) Frequency
   - B) Amplitude
   - **C) Damping**
   - D) Acceleration
7) The frequency at which an object tends to vibrate when hit, struck, plucked, strummed or somehow disturbed.
   - A) Stiffness
   - **B) Natural Frequency**
   - C) Amplitude
   - D) Resonance

Appendix B

Plate Tectonics Post-Assessment Quiz

Directions: Please pick the correct term for the following definitions to the best of your knowledge.

1) The number of complete cycles of a periodic process occurring per unit time
2) Intensification and prolongation of sound, especially of a musical tone
3) The maximum absolute value of a periodic curve measured along its vertical axis
4) The rate of change of velocity with respect to time.
5) Difficult to bend; rigid.
6) To decrease the amplitude of (an oscillating system).
7) The frequency at which an object tends to vibrate when hit, struck, plucked, strummed or somehow disturbed.

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A WORD BANK WAS USED WITH MORE THEN THE FOLLOWING ANSWERS

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frequency
resonance
amplitude
acceleration
stiffness
damping
natural frequency

Appendix C

<u>Grading Rubric for Plate Tectonics Structure Testing (Group Portion)</u>

Component	0 points	2 points	3 points	4 points	5 points	Point Value
Rationale	None present	Very little information/ not clear.	Some information, but not clear	Information adequate, but unclear	Informative and clear.	5 points
Structure	None present	Structure is partially finished	Structure is finished and able to be tested	Structure displays creativity in design	Structure performs very well during testing	5 points
Foundation	None present	Partially thought out foundation	Foundation is present and does its job	Creativity in the use of materials, Secure foundation	Foundation performs very well during testing	5 points
TOTAL						15 points

Appendix D
Module Lesson/ Activity Review Checklist

Activity Title: Earthquakes

These reviews occur in the fall for each lesson activity that is created as part of a module. Up to four people review each lesson activities, including a teacher, another fellow, and a faculty member. This sample review was completed by the undergraduate fellow.

1 – Strongly Agree
2 – Agree
3 – Disagree
4 – Strongly disagree
NA – Not my expertise, Cannot answer

	1	2	3	4	NA
This activity is aligned with the science standards.	X				
This activity is aligned with the math standards.					X
This activity is aligned with the technology standards.		X			
This content of this activity is accurate.	X				
The content in this activity is developed in a way that will promote student understanding.	X				
The activity will be interesting to most students.		X			
The activity requires active participation of the students in their own learning.	X				
The activity frames the content in a real life situation.	X				
The activity frames the content using an engineering related concept.	X				
The activity is adaptable to various school settings.		X			
The activity requires discussion and reflection on the part of the student.	X				
The activity appropriately incorporates technology.	X				
The activity includes a formative assessment plan.		X			
The activity includes a summative assessment plan.		X			
The activity is highly innovative.	X				
The activity requires students to reach high levels of thought processes.	X				
The activity is clearly written and carefully edited.		X			
The activity has the potential to be published.					X
The activity has the potential to be produced commercially.					X

Appendix E call this on the Web

Web Resources Related to Lesson on Plate Tectonics

Picture Link of Activity

Copy and paste the following link in any web browser and you will be sent to a sight with all the pictures taken during the lesson:
http://share.shutterfly.com/osi.jsp?i=EeAM2zdyybMWzio

Using the first 3 digits of the pictures you can follow along with what day it is taken on.

Research (Online Links Used)

Guitar Resonances:
http://www.guitarnotes.com/notes/noteget.cgi?guitar_resonances
Natural Frequency:
http://www.biowaves.com/Physics/Sound/NaturalFrequency.cfm
Playing/ Showing Guitar resonance:
http://www.phys.unsw.edu.au/~jw/guitar/intro_engl.html
Guitar notes and their frequencies:
http://www.phys.unsw.edu.au/~jw/notes.html
Guitar string composition:
http://www.playrecord.net/resource/articles/guitar-strings.html
Guitar types – Resonator Guitar:
http://www.playrecord.net/resource/articles/guitar-strings.html
Liquefaction link:
http://www.cen.bris.ac.uk/civil/students/eqteach97/geo2.htm

Online Plate Tectonic Animations – used during Day 4

1) Motion of the Plates:
http://www.thetech.org/hyper/quakes/plates/tectonics.html
2)Earth everchanging Face:
http://www.pbs.org/wnet/savageearth/animations/hellscrust/
3) Animation of the earth's land masses moving:
http://www.odsn.de/odsn/services/paleomap/animation.html
4) Southern Cali Earthquake Data Center:
http://www.data.scec.org/
5) Downloadable animations on land formations over time:
http://www.geol.ucsb.edu/Outreach/Download/Freeware-FR.html
6) Earthquakes for kids:
http://earthquake.usgs.gov/4kids/
7) Global Earthquakes animations:
http://home1.gte.net/bridavis/eq.htm

Biographical Information

LAURA A. KOEHL, doctoral student, Educational Foundations, CoEdu, UC. Her research focuses on the experience of women scientists. She has served for the past three years is the evaluation fellow for the STEP project. Ms. Koehl worked in college administration for 16 years prior to her enrollment at UC serving as Vice President for Student Development at Thomas More College for 10 years.

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NICHOLAS B. HARTH, Masters student, Electrical Engineering, CoEng, UC. During the past three years, he has been a fellow working for Project STEP, the NSF funded grant under which this work was produced. His research focuses on manufacturing and characterization of Organic Light Emitting Diodes (OLEDs) through the use of rare-earth sulfides as the cathode.