Shake and Break! Earthquake Challenge

Jayma Koval, Research Associate, Georgia Tech
Marion Usselman, Principal Research Scientist, Georgia Tech
Mike Ryan, STEM researcher, Georgia Tech

Abstract

Shake and Break! is a 1-week instructional module for core middle school science, developed as part of the National Science Foundation funded *Advanced Manufacturing Integrated to Unlock Potential* (AMP-IT-UP) project (NSF # 1238089). It is aligned with the Next Generation Science Standards (NGSS) and Standards of Mathematical Practice (SMP) and focuses on basic concepts of seismology, spatial and temporal data, and data practices related to data visualization. In this module students explore different ways of representing earthquake data to better communicate findings and integrates geoscience content with the practices of analyzing and interpreting data.

Introduction

In 2012, the National Science Foundation funded the *Advanced Manufacturing Integrated to Unlock Potential* (AMP-IT-UP) project through its Math and Science Partnership program to develop a comprehensive initiative to increase student interest and engagement in STEM (NSF #1238089) A central outcome of the project was a series of one-week modules for core middle school math and science instruction, aligned with best practices put forth in the Next Generation Science Standards (NGSS 2013) and the Standards of Mathematical Practice (National Governors Association Center for Best Practices & Council of Chief State School Officers 2010). The modules promote STEM learning by engaging students in project-based inquiry lessons that highlight scientific research and emphasize collecting, representing, visualizing, interpreting, and communicating authentic and compelling data. Though all modules require students to collect, graph, and analyze data, each module also specifically focuses on one of three general data practices—1) Experimental Design; 2) Data Visualization; and 3) Data-Driven Decision Making.

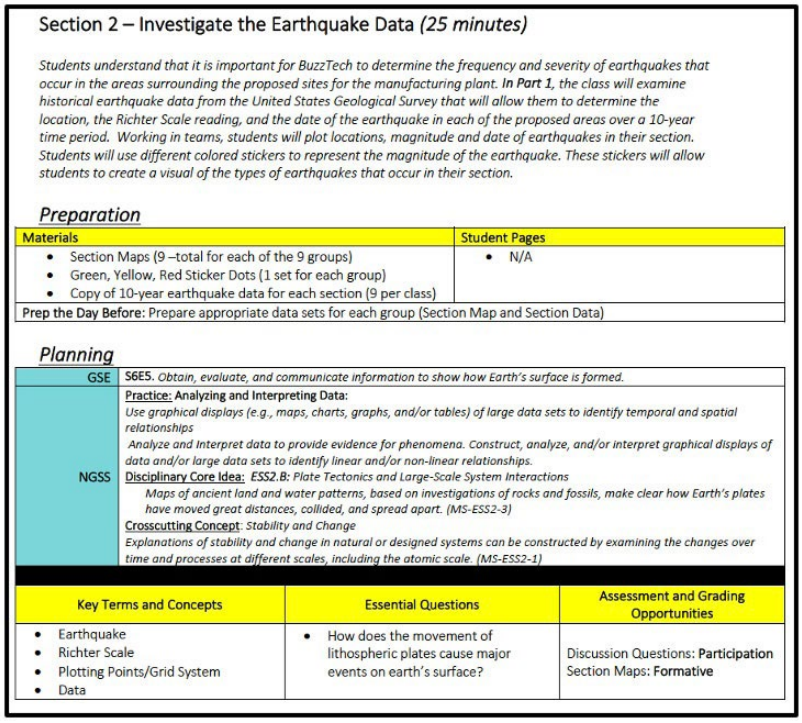
All modules also strive to promote, to the extent possible, the integration of the STEM content, incorporating science and engineering contexts and data collection investigations into activities that also require that students analyze data using both grade-level appropriate and foundational mathematics skills. Three of the science modules are contextualized within earth systems, challenging students to collect and analyze data regarding earthquakes, volcanoes, and weather. The earthquake module, a middle school science module entitled *Shake and Break!*, is presented in detail below. All other modules are also available for free download at ampitup.gatech.edu.

Overview

Shake and Break! is a week-long science module that focuses on basic concepts of seismology, spatial and temporal data, and data practices related to data visualization—i.e. how data can be represented in different ways to communicate various messages to an audience. During this investigation, students analyze earthquake data to help the Buzztech company decide where to build its new manufacturing plant. The module was designed for middle school science classes but also connects to math concepts such as coordinate systems and mapping. Like all AMP-IT-UP modules, it follows the BSCS 5E instructional model that is based on the constructivist theory of learning and allows for students to construct their own knowledge based on experiences (Bybee et al. 2006).

Background Information for Teacher

The instructional materials, which are all available for free download at resources.ceismc.gatech.edu/amp/earthquake, were created and revised based on years of classroom implementation through the AMP-IT-UP project. The student materials include a student edition text that guides students through the experience and the accompanying student worksheets that students use to showcase what they are learning. The materials also include teacher instructions to help educators implement the modules successfully. The teacher edition is the student text that has been annotated with tips and suggestions to help guide students through the module. The annotations include sample answers that students might give to questions, reminders to prepare materials ahead of time or additional content to explore. The teacher preparatory guide is intended to help teachers plan their lessons. It contains information that might be required in lesson plans such as relevant standards, essential questions, and key terms; provides a synopsis of each section of the module; and visually maps the module content onto the 5E learning model (bscs.org/bscs-5e-instructional-model/). The main activity in *Shake and Break!* uses maps and different colored stickers that are used for plotting the location and magnitude of earthquakes.



Section 2 – Investigate the Earthquake Data *(25 minutes)*

Students understand that it is important for BuzzTech to determine the frequency and severity of earthquakes that occur in the areas surrounding the proposed sites for the manufacturing plant. In Part 1, the class will examine historical earthquake data from the United States Geological Survey that will allow them to determine the location, the Richter Scale reading, and the date of the earthquake in each of the proposed areas over a 10-year time period. Working in teams, students will plot locations, magnitude and date of earthquakes in their section. Students will use different colored stickers to represent the magnitude of the earthquake. These stickers will allow students to create a visual of the types of earthquakes that occur in their section.

Preparation

Materials	Student Pages
• Section Maps (9 –total for each of the 9 groups) • Green, Yellow, Red Sticker Dots (1 set for each group) • Copy of 10-year earthquake data for each section (9 per class)	• N/A

Prep the Day Before: Prepare appropriate data sets for each group (Section Map and Section Data)

Planning

GSE	**S6E5.** *Obtain, evaluate, and communicate information to show how Earth's surface is formed.*
NGSS	**Practice: Analyzing and Interpreting Data:** *Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships* *Analyze and interpret data to provide evidence for phenomena. Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and/or non-linear relationships.* **Disciplinary Core Idea:** ***ESS2.B:*** *Plate Tectonics and Large-Scale System Interactions* *Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart. (MS-ESS2-3)* **Crosscutting Concept**: *Stability and Change* *Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale. (MS-ESS2-1)*

Key Terms and Concepts	Essential Questions	Assessment and Grading Opportunities
• Earthquake • Richter Scale • Plotting Points/Grid System • Data	• How does the movement of lithospheric plates cause major events on earth's surface?	Discussion Questions: **Participation** Section Maps: **Formative**

Figure 1. Sample content from the teacher preparatory guide for *Shake and Break!*

Preparation

During this activity students work with temporal and spatial data and discover the importance of data visualizations. Each group of 2-3 students is given one section of a larger map, earthquake data for their particular section, and multicolored stickers for plotting the data. For the initial activity students are given 10 years of earthquake data to plot on their maps and analyze. Later, students are given 40 years of data to plot and analyze. Since each group receives only one section of the entire map, they need to combine their map sections after all data has been plotted to create the larger map and reveal the complete data profile.

It is recommended that group size is limited to two students, three at a maximum. There is plenty of work to divide among a pair of students but a third student might get restless. Two different groups can be given the same section maps to plot if class size warrants it. To accommodate students with special needs, the map sections can be enlarged, the dataset size can be increased or decreased, and the sticker colors or textures modified. Adaptations for online learning are also included on the curriculum materials website, as described below.

Engage

The Engage phase is designed to capture student interest and connect them with a real-world problem. The module text introduces students to the BuzzTech company, a cell phone and tablet manufacturer that wants to open a new plant in northern California. BuzzTech has selected three possible sites for consideration and students are challenged to assist BuzzTech with selecting the winning site. Students are given highway maps and relief maps to familiarize themselves with the area. Making a recommendation will not be straightforward as students have to evaluate the advantages and disadvantages of each location including land costs, the availability of employees for commuting, transportation options for manufactured goods, and perhaps more significantly, earthquake activity.

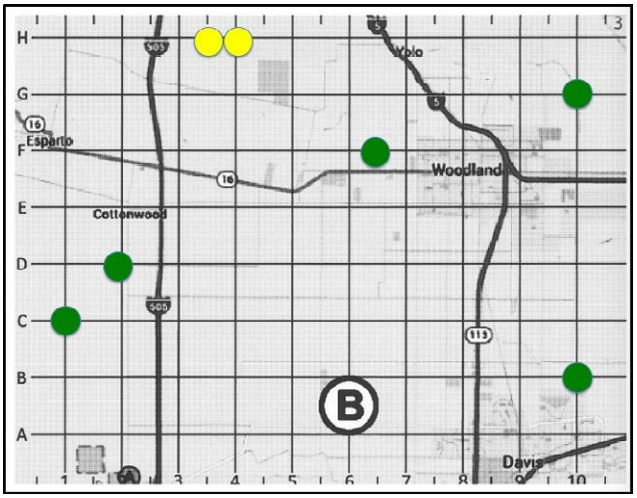


Figure 2. Section map displaying 10 years of earthquake data.

Explore

In the Explore phase students actively investigate the problem by analyzing ten years of earthquake data. The map of the area that BuzzTech is considering has been divided into 9 sections. Students, working in groups of 2-3, are assigned a section of the original map on which to plot their earthquake data. The materials that students use for this activity are their map section print out, a set of green, yellow and red sticker dots, and a copy of the United States Geological Survey (USGS) earthquake data for their assigned section. Students use the stickers to plot the location of earthquakes on their maps, and the colors of the stickers represent the earthquake magnitude according to the Richter Scale: green (0.0-3.0), yellow (3.1-6.0), red (6.1-10.0).

After students plot their data, they engage in a class discussion reflecting on their map sections and consider, based on their information so far, whether their map sections would be a good choice for the plant location.

Shake and Break! stresses the skills and concepts associated with data visualization. Therefore, in this module students take the earthquake data given to them in charts, which includes location and magnitude, and they find different ways of representing the data to better communicate a message. The stickers quickly communicate the earthquake location while the use of color communicates the strength of the earthquakes on the Richter scale in that area.

Explain

During the Explain phase, learners connect what they have done so far with the required science standards that include plate tectonics and large-scale system interactions, analyzing and interpreting data, and stability and change. The student text includes an "*Add to Your Understanding*" section that introduces disciplinary content relevant to the challenge (earthquake basics, and how earthquakes are detected and measured) and provides links to two videos to support student learning. The first video, *Earth Without Water*, simulates the removal of water from Earth to show the actual surface of the planet, highlighting the topography of deep trenches and mountain ranges. The second video, *Earthquake Samples*, contains actual footage of impacts and damage caused by earthquakes, with some of the earthquakes occurring in real time. It features several earthquakes (4.4 to 9.0 on the Richter Scale) to help students visualize the range of earthquake damage and intensity. Students use this content to reflect back on the challenge and what it means for the sites that BuzzTech is considering. Students previously plotted 10 years of earthquake data on their section maps. Now they reflect back on those maps and consider whether the number and magnitude of earthquakes is in a range that BuzzTech can tolerate.

Elaborate

In the Elaborate phase, students extend their understanding of the content they have learned thus far (plate tectonics and data representation) to new experiences, including how researchers use satellites and global positioning systems (GPS) to predict when earthquake activity is likely to occur. However, in order for students to best assist BuzzTech with determining a location for their plant, they need more data. They are therefore given 40 years of data to plot so they can observe differences in seismic patterns over time. Students follow the same procedure as before and use the same colored stickers to represent both the location and magnitude of the earthquakes plotted on their map section. Once students have plotted their data, they again interpret the results, pondering whether the site seems like a good choice for the Buzztech plant location.

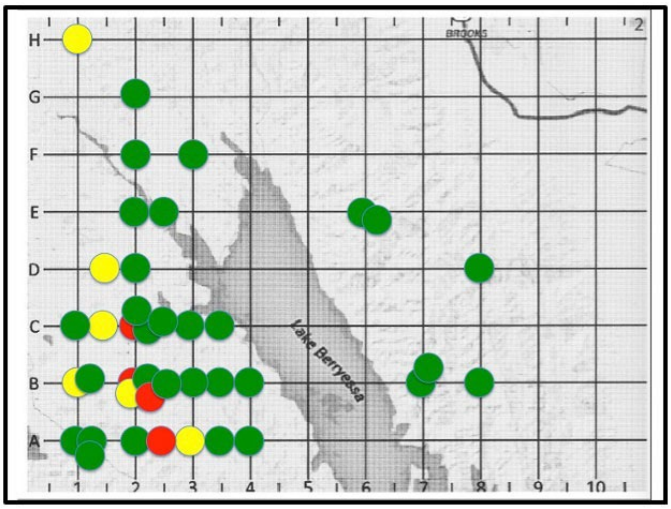


Figure 3. Section map displaying 40 years of earthquake data.

Shake and Break! is a data visualization module. While students are learning more about earthquakes and assisting BuzzTech, they are also learning about the value of visualizing data to best communicate scientific findings to other scientists and the public. In *Shake and Break!* students also learn about temporal and spatial data. Forty years of earthquake data (temporal data) give students insight into how earthquake patterns may have changed over time. When students combine their sections to reassemble the larger map of the area that BuzzTech is considering, it shows how the earthquake data changes across a geographic area (spatial data). The larger map reveals clear patterns of earthquake activity, allowing students to make better informed recommendations to BuzzTech.

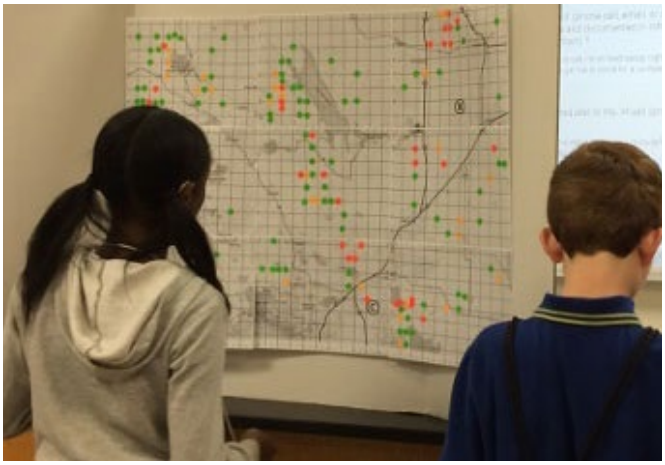


Figure 4. Student group analyzing the completed earthquake map during the Evaluate phase.

Courtesy of Sabrina Grossman.

Evaluate

There are multiple opportunities to evaluate student learning through both formative and summative assessments during this module. The student pages are essentially practice, guiding students in this experience as they plot their earthquake data onto their section maps. For teachers looking for formal grades, the student page *Letter to BuzzTech*, is recommended for a summative assessment. This assignment gives students a scaffolded letter to help them communicate their site recommendation to BuzzTech. When making recommendations, students consider the larger reassembled map showing earthquake activity as well as the chart listing advantages and disadvantages of each site location. There is no straight-forward recommendation to make; students have to weigh all of their available information to make the best-informed decision possible.

Conclusion

This STEM-integrated earth science module connects students with real-world scenarios and uses authentic science, mathematics and social studies data. Although it is intended primarily for 6th grade science classes, the content and student pages can be adapted for students of varying abilities, additional grades, or even different subjects such as mathematics enrichment. This activity can also be used for virtual, online instruction. Students, in lieu of having physical materials, insert images of their assigned map sections into PowerPoint or Google Docs. They then digitally draw green, yellow and red circles onto their maps to identify the earthquakes, save their files as pictures and share the completed files with their teachers. Teachers can then use software such as Adobe

Table 1. Middle School History of Earth
https://www.nextgenscience.org/topic-arrangement/mshistory-earth

Performance Expectation

MS-ESS2-2. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

Science and Engineering Practices
Analyzing and Interpreting Data • Analyze and interpret data to provide evidence for phenomena.
Constructing Explanations and Designing Solutions • Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe nature operate today as they did in the past and will continue to do so in the future.
Disciplinary Core Idea
ESS2.A Earth's Materials and Systems • The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.
ESS2.B Plate Tectonics and Large-Scale System Interactions • Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided and spread apart.
Cross-Cutting Concepts
Scale Proportion and Quantity • Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

About the Authors

Jayma Koval is a Research Associate at Georgia Tech, where she focuses on STEM-integrated curriculum development and teacher professional learning. She taught middle school science for 10 years in New York and Georgia and is passionate about strengthening earth science education. She received a B.S. in Meteorology from the Pennsylvania State University, a M.S. in Earth Science Adolescence Education from Long Island University and an Ed.S. in Teaching and Learning Earth Science Education from Georgia State University. Jayma can be reached at Jayma.Koval@ceismc.gatech.edu

Marion Usselman is a Principal Research Scientist at Georgia Tech, and Associate Director for Development and Educational Innovation at CEISMC. She received a B.A. in Physics/Biophysics from the University of California, San Diego and a Ph.D. in Biophysics from the Johns Hopkins University. She was the Principal Investigator on the AMP-IT-UP project and has worked for many years to promote K-12 STEM education and develop robust university-school partnerships. Marion can be reached at Marion.Usselman@ceismc.gatech.edu

Mike Ryan is a 25-year STEM researcher at both Georgia Tech and the University of Kansas, a curriculum developer, and a teacher professional learning leader, with a focus on project-based learning. He is the author of multiple K-12 STEM curricula, including *Project-Based Inquiry Science - PBIS* (Activate Learning). He currently consults schools, organizations and projects in PBL, inquiry, curriculum development, professional & online learning. Mike can be reached at ryanmike@umich.edu.

Photoshop to create the full map containing 40 years' worth of earthquake data.

For five years AMP-IT-UP curriculum developers, researchers and educators designed the curriculum materials, piloted them in four diverse middle schools, made iterative changes based on formative data, and conducted extensive empirical research regarding their impact on students and teachers (Alemdar et al., 2018). *Shake and Break!* and the other AMP-IT-UP modules demonstrate how project-based learning and the implementation of integrative practices related to data science can effectively enable students to master core math and science disciplinary concepts and practices while promoting high levels of student engagement (Newton et al. 2019). All AMP-IT-UP curriculum offerings are available at resources.ceismc.gatech.edu/amp/.

Acknowledgements

We would like to thank the following people for contributions during the development and assessment of the Shake and Break! module: The educators from Griffin-Spalding School System, Sabrina Grossman, Meltem Alemdar, Jessica Gale, Sunni Newton, Stefanie Wind, Andrew Newman, William Jimerson, Mary Levine, James-Addis Hill, and Steven Taylor.

References

Alemdar, M., J. Gale, J. Lingle, R. Moore, J. Rosen, M. Usselman. (2018) The impact of a middle school engineering course on students' academic achievement and non-cognitive skills. *International Journal of Education in Mathematics, Science, and Technology* (IJEMST) 6(4), 363-380

Bybee, R.W., Taylor, J.A., Gardner, A., Van Scotter, P., Carlson Powell, J., Westbrook, A., & Landes, N. (2006). *The BSCS 5E instructional model: Origins and effectiveness*. Colorado Springs, CO: BSCS.

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common Core State Standards for Mathematics*. Washington, DC: Authors

Newton, S., Alemdar, M., Koval, J., Gale, J., Grossman, S., Wind, S., Ryan, M., & Usselman, M. (2019). Evaluation approach: Practice-focused middle school science modules. Journal of Research in STEM Education, 5(2), 170-188.

NGSS Lead States. (2013). Next Generation Science Standards: For States, by States. Washington, DC: The National Academies Press