“Cheap and Dirty” Classroom Simulation

of the

Sudbury Impact

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Developed as an Ancillary or Replacement Activity for

EarthComm: Earth System Science in the Community:
Unit V: Earth System Evolution
Chapter 1: Astronomy… and Your Community
Activity 4: “Impact Events and the Earth System”

Introduction

Statement of Problem

The state of Michigan requires Earth Science coursework at the high school level as indicated in the state's "High School Content Expectations," or "HSCEs." For various reasons, many school districts in Michigan have enacted an Earth Science course at the 8^{th} grade level. This causes problems. Foremost among these is that 8^{th} grade students typically have trouble achieving adequate understanding of high school-level content due to a lack of cognitive and conceptual development, inadequacy of mathematical and reasoning skills, and age-level behavioral issues. Another potential problem arises with regard to teacher preparation and certification requirements that are different for middle level educators and their high school colleagues. This problem may be exacerbated by the selection of texts and learning materials written for students with reading and mathematics performance levels characteristic of students at the midpoint of their high school careers.

It is against this backdrop that the Sudbury Impact Classroom Simulation has been developed. Several teachers in the Grand Rapids Public Schools, participating in the inaugural cohort of the NSF-funded, Math-Science Partnership, "MiTEP" (Michigan Teaching Excellence Program) indicated frustration with an activity found in *EarthComm* (a high school textbook adopted by GRPS for use in the district's 8^{th} grade Earth Science course). The aforementioned activity is called "Impact Events and the Earth System," and contrary to the adoption of the 5e learning model by GRPS, this activity begins with an "Investigate" activity that merely engages the students in a mathematical exploration of impact events. The mathematics is complex (e.g. "$M = 0.67 \log_{10}E - 5.87$ where M is the equivalent magnitude on the Richter scale and E is the energy of the impact, in joules”). Teachers complained that even *they* had difficulty navigating the activity. They expressed an interest in developing an “explore” (5e equivalent of an “investigate” activity) that would allow students to gain qualitative, conceptual understanding of the impact phenomenon, either as a replacement for the existing activity or as a preliminary exercise.

Intended Outcomes

The goals for the original activity are taken directly from “EarthComm” (p. E37):

> *In this activity, you will:*
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> - *Investigate the mechanics of an impact event and make scale drawings of an impact crater.*
> - *Calculate the energy (in Joules) released when an asteroid collides with Earth.*
> - *Compare natural and man-made disasters to the impact of an asteroid.*
> - *Understand the consequences to your community should an impact event occur.*
> - *Investigate the chances for an asteroid or comet collision.*

An additional outcome for the ancillary activity is to provide students with a physical model of a scale model collision. This simulated impact will include inquiry, measurement, mathematical calculations, and variable manipulation.

Materials

The replacement activity employs a 2’ x 2’ x 6” sand pile (*slightly* moist beach sand is preferable to dry dune sand, although having *both* types available allows for an additional variable), various impactors (bowling ball, baseballs, golf balls, and rock samples of various sizes, shapes, and textures), several 6'x 9' plastic tarps or sheets of "visqueen" (1 per group of 4 students, marked with uniformly radiating concentric circular arcs struck from the center point of one of the short tarp edges), a whisk broom and dustpan, kite string, protractors, and a balance for each group. Access to a digital video and/or still camera would also be desirable. The arrangement will be similar to the left half of the concentric circles in the diagram below, showing the impact site of the 1.849 ga Sudbury impact and the location of distal ejecta discovered in northeastern Minnesota:

Safety Considerations

-Observers must stay a safe distance from the group member initiating the impact and must be located *behind* the initiator for non-perpendicular (*glancing)* impacts.

-Don't goof around.

The Lesson

Instructor Presented Background Material

Because this is both an “engage” and “explore” activity, prior background material will not be provided by the instructor in this activity. The teacher *will* describe the safety considerations included above prior to initiation of the activity.

Activities

Day 1

1. At the beginning of class, show a film segment of a golfer executing an “explosion” shot from a sand bunker. This could be from YouTube or from a televised golf tournament, but it may have more “impact” if the teacher is actually executing the shot shown in the video. Stop the video just before the impact occurs. Ask students (individually) to make a rough sketch in their journals of how they think the pattern of the “sprayed” sand will look. Label it “normal.” If journals are not used, worksheets showing 4 boxes may be prepared ahead of time. (5 minutes)

2. Ask the students to create a diagram showing the expected spray pattern produced by a golfer swinging with TWICE the force of swing. Label it “double force.” (2 minutes)

3. Ask the students to create a diagram showing the expected pattern of sprayed sand that would be produced if the club was just pounded vertically straight down on the sand. Label it “vertical impact.” (2 minutes)

4. Ask the students to create a diagram showing the expected pattern of sprayed sand if the “normal” impact had occurred when the sand was moist. (2 minutes)

5. Ask the students to pair up with a partner and discuss their findings with each other. In the think-pair-share method, this is the “pair” segment. (4 minutes)

6. In the “share” segment, ask pairs of students to elaborate on their discussion related to one of the impact variables, chosen by you. It may be necessary for two or more groups to share their findings on the same variable. (10 minutes)

7. Summarize the findings, addressing any misconceptions or questions about the impact, but do not attempt to “correct” their work. (5 minutes)

8. Introduce the activity, including the “impactors” they’ll be using. Stress the safety factors indicated above. Ask the students to discuss with their partner how the change from a golf club to a tossed or dropped impactor onto sand will change the spray pattern for the 4 variables above. (2 minutes)

9. Allow pairs to volunteer their ideas with the class. (4 minutes)

10. Ask pairs to consider any other variables that might be interesting to investigate. (2 minutes)

11. Allow pairs to volunteer their ideas with the class, keep track of the new ideas on the board. Hopefully, “size of the impactor” and other similar variables will emerge. (4 minutes)

12. Create a list on the board of the following variables: Allow groups to identify one variable to investigate, using some type of lottery method. Groups can be consolidated so that two pairs will work together. (5 minutes)

-force

-angle

-sand moisture

-size of impactor (mass and/or volume)

-others as indicated by students

13. Describe the equipment available. Reveal that the tarp or visqueen will be used to collect the ejected sand, and hint that "amounts" of sand on various sections of the sheet can possibly be determined. Don't be specific (that will be part of the closure of the day's activity and a prescription for the following day, after they've performed their experiments. (2 minutes)

13. Working in groups of four, students brainstorm an experimental design (to be turned in by each member of the group, paper-clipped together), including number of trials, equipment used, and a brief description of the procedure. Also ask them to figure out a way of "quantifying" the experiment (15 minutes)

14. Hand in your work.

Day 2

From the previous day's submissions, create a summary for the class showing what each group has developed. As you go through each one, ask students in other groups to offer suggestions regarding improvements. You should also offer prompts and encouragement if you have suggestions or questions. This may be a good time to review the nature of science, changing only one variable, repeatability, and the need for all students to be involved. This is also the ideal time to synthesize a method for measuring the amount of ejecta at various positions on the tarp. (10 minutes)

1. Go outside in an area shielded from the wind and review the safety instructions. Inform them of the set-up, answer their questions, and help them negotiate the logistics of the activity. (10 minutes)

2. Allow students to conduct their investigations. Inform them that they will be presenting their findings at the end of the class period. Circulate among the groups to ensure that they are remaining engaged and that they are communicating respectfully and effectively. Engage the groups in the quantification methodology for their particular trial, draw scale diagrams, (the tarp should be indicated as a box in the students' journals, or in handouts provided) and encourage them to make the measurement of mass of sand in each circular arc cross section (whisk broom and dustpan). If you have video or still camera availability, it may be interesting to capture images of some or (preferably) all of the investigations. (30 minutes).

3. Clean up the mess and return the equipment to its original condition and location. (10 minutes)

Day 3

EarthComm activities can be resumed at this point, or the teacher may decide to offer closure on the activity without actually conducting the mathematically rigorous energy calculations. The latter should include graphing opportunities, (grams of sand mass vs. arc segment), comparisons between predicted patterns and those actually shown, and a heavily pixelated satellite photo of the Sudbury Impact site (included in the folder containing this activity). Also included in the folder are:

- A link to the "Up-Goer Five" writing strategy (and an example created from the PhD dissertation abstract of Alexandria Guth by the author) and two actual abstracts from papers written about the Sudbury Impact. The abstracts are found in their original form and also in a highlighted form, which can be distributed to groups of students and “upgoer-five-jig-sawed” by these groups sorted by highlight color.

- A link to a You-Tube video featuring Dr. Neil DeGrasse-Tyson discussing potential future impacts. Another You-Tube video shows a super-slow motion red liquid droplet which displays the description of Dr. Tyson nicely.
- Assorted support materials, including a Wikipedia entry for “Animikie Group.” It is believed that the Sudbury Impact led to the cessation of the banded-iron formation in the iron ranges of Minnesota, Wisconsin, and Michigan.
- Ballistics for really fast bullets fired from a rifle and a projectile range simulation that students can use to find approximate ejecta velocities that would provide a distance range of 800 km. Results are startling. However, it should be noted that the 800 km is the furthest distance between distal ejecta and the impact site *today*. Location of the site 1.85 ga was closer to the earth’s equator then, the rate of rotation was greater, and the 1.1 ga Midcontinent Rift affected the contributed to today’s 800 km distance.

Strategies for Promoting Student Inquiry

These are embedded throughout the activity. Students are asked to make predictions, revise their thinking, consider individual experimental variables, and to explore similarities and differences among several variables.

Assessment of Learning

1. Completion of Journal entries (or completion of worksheets) with diagrams utilizing district-adopted or teacher developed assessment rubric.

2. Observation of Engagement

3. Performance on formative assessment instrument (if used) and/or on district common assessment. Some possible questions:

-How are the amount of force between the impactor and the sand related?

-How is the variable mass of the impactor related to the material spray (also called "ejecta") pattern?

-Were any of your initial predictions of sand patterns from the first day way different from your observations? Explain.

-Look at a diagram of the Sudbury Impact. Can you identify similarities between the diagram and the experiments performed by your class?

-Do you think that the Sudbury impact crater was created by an impactor that struck vertically? What evidence do you have for your claim?

-Material released from the impact is found in Northern Minnesota. Find Sudbury and the western border of Minnesota on a map or globe. How far did the ejecta travel in that direction?

-Optional: View "Armegeddon" and/or "Deep Impact" and identify at least 5 legitimate hazards that might be initiated by a comet or asteroid impact. Also identify 5 parts of the movie(s) that you think are exaggerations or worse.

Selected websites for further research:

http://www.uwsp.edu/geo/projects/geoweb/participants/dutch/Sudbury/GSA2001.htm

http://ottawa-rasc.ca/wiki/index.php?title=Odale-Articles-Wanapitei

http://en.wikipedia.org/wiki/Sudbury_Basin

http://rst.gsfc.nasa.gov/

References

Smith, Michael, Southard, John B. (Eds.) 2005. *EarthComm (Earth System Science in the Community)*. Armonk, NY: It's About Time, Inc.

Klasner, John S., Bornhorst, Theodore J. (Eds). 2008. *Field Trip 5, in Proceedings Volume 54: Institute on Lake Superior Geology*.