
OVERSIZE LOAD

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Fracking: Drilling into MATH AND SOCIAL JUSTICE

15.3

1,238,780

A community-focused lesson that allows students to explore and model their findings with mathematics can also produce students who are aware of the environment.

"Why are we studying fracking in math class?" one student asked when I introduced the week's activity. My goal was for my students to build a mathematical model that could help them understand a community issue. But did they get the point of the lesson?

Mathematical modeling, a focus of the Common Core State Standards for School Mathematics (CCSSI 2010) and one of the Standards for Mathematical Practice, is generally considered to be the process of exploring a real-world situation and making sense of it using mathematics (Lesh and Zawojewski 2007). Teachers need to create opportunities for students to use mathematics to make sense of real-world situations.

Typically, mathematical modeling takes the form of a cycle of creating a representation of a real-world phenomenon, analyzing the result, and revising the model. This often involves making decisions and simplifying a complex scenario to represent it mathematically. In the Common Core, a modeling activity consists of students applying mathematics to everyday and societal problems. For example, students are to "identify important quantities in a practical situation" and "analyze . . . relationships mathematically to draw conclusions" (CCSSI 2010, p. 7). However, as an early-career teacher in a school district transitioning to the Common Core, I had little experience teaching mathematical modeling. One of my goals is to teach mathematics for social justice, helping students see the value of math as a powerful tool for understanding social issues. I hope that my students will become critical participants in the world, asking questions and using mathematics to make sense of what is happening around them. Mathematical modeling provided a logical approach for a social justice–themed lesson about hydraulic fracturing.

WHAT IS FRACKING?

Fracking is shorthand for hydraulic fracturing, a method of extracting natural gas from the earth. This is a current hot-button issue for our community. High levels of shale have recently been identified in our rural, high-poverty area, and oil and gas companies have begun offering landowners large sums of money to allow drilling on their land (Hunt 2012; Smith 2013). However, environmental advocates have concerns about the lasting effects of fracking. The local newspapers have been filled with letters and editorials on both sides of the debate: Should the community ban fracking, or should individuals take advantage of the money?

Fig. 1 Students brainstormed general questions about the topic of fracking.

How much does the owner of the well and land make minus the expenses?

How much money in resources do we get out of the ground from fracking?

How many gallons of water does it take to break up all the rocks to get the resources?

How much do the companies make?

What is in the toxic water and how can you get rid of it in a safe manner?

How can you try to find out how (if it does) affect the future?

My students were aware of the debate, but they did not fully understand the process of fracking or possible effects on the community. Because fracking was so close to home, the topic was ripe for a mathematical exploration.

In the following sections, I will describe the challenges faced during a lesson that allowed my students to model a real-world situation using rich mathematics.

TEACHING MATHEMATICS FOR SOCIAL JUSTICE

I was somewhat concerned about the repercussions of presenting a controversial issue in school. In my school district, mathematics is generally taught as culture-free and controversy-free, so I have never encountered resistance to the topics I teach. According to Corbett (2007), some families in rural areas believe the values of the school compete with values at home. Introducing an exploration of the environmental effects of fracking might isolate parents who value the financial aspects of fracking.

I also considered the balance of social justice and mathematics. Researchers of critical mathematics education, such as Vithal (2003) and Gutstein and Peterson (2005), inspired me to design my own engaging, community-centered social justice lessons. However, I am often disappointed with either the students' lack of mathematical exploration or the students' levels of understanding of the social issues. These researchers also acknowledged the difficulty of finding the delicate balance between mathematics and social justice. I was concerned that too much freedom to explore environmental interests might inadvertently limit my students' mathematical explorations.

INCORPORATING HIGH-LEVEL MATHEMATICS

The activity sheet I originally used to teach students about fracking led students step by step through complex multistep percentage problems that were related to facts about chemicals and water consumption used in fracking (Smith 2012). However, it gave the students so much guidance that the problems lost context and became procedural. Students did not engage in the cognitive challenges required to represent a situation or choose an appropriate procedure.

I realized that to increase the cognitive level of the lesson, I needed to present my students with messy situations. While developing the new activity sheet, I spent a significant amount of time organizing and simplifying messy data. According to numerous constructivists (e.g., Piaget 1976), people learn by actively constructing new knowledge and infusing it with personal meaning. I decided that my students should choose an aspect of fracking to explore; sift through websites, articles, and data sets; make sense of messy information; and make decisions about the importance of information.

Mathematical modeling is one way that students can engage in these rich learning opportunities. Although concerned that I did not have the answers to every question my students posed and would be unable to guide them toward understanding the problems mathematically, I knew that the opportunity to develop their own mathematical models would be a rich learning experience.

INTRODUCING THE MODELING ACTIVITY

The lesson began with a full day of learning about fracking through science. Many students were already familiar with the concept and were eager to share their knowledge and experience. Most students had negative perceptions of fracking and explained that it was bad for the environment. One student said that her family was offered money to allow fracking on their property, but they turned it down. Students discussed reasons why some people might allow fracking, including using the money to pay for college or a mortgage.

Next, students watched a National Geographic video and read some local newspaper articles from both sides of the fracking debate. These sources gave students general background knowledge and information about community concerns. Students also reflected on the question, "How do you think math can be useful in understanding issues like fracking?"

The students then brainstormed questions related to our topic (see **fig. 1**). The questions, in turn, were written on the board as a master list. I asked students which questions

involved math or could be answered mathematically and how. After this discussion, each student chose one question to explore, such as "How much waste is put underneath our water system with one well?" and "How many hydro power plants does it take to generate the same amount of power as a fracking well produces in one day?"

The students investigated their questions, created a mathematical model of the answer, and designed two presentation slides. One slide included the student's question and answer, and the other slide described the mathematics the student used.

MODIFYING THE RESEARCH QUESTION

Many students faced challenges when they began researching their question. Some students had difficulty finding information, either because it was unavailable (e.g., "How does fracking affect animals?") or because the research question was too broad (e.g., "What percentage of the United States uses fracking?"). In these situations, I encouraged students to find an indirect way to answer their question or focus on one aspect that they could answer. Students were also urged to focus on the numbers, to figure out what they meant and how to explain them.

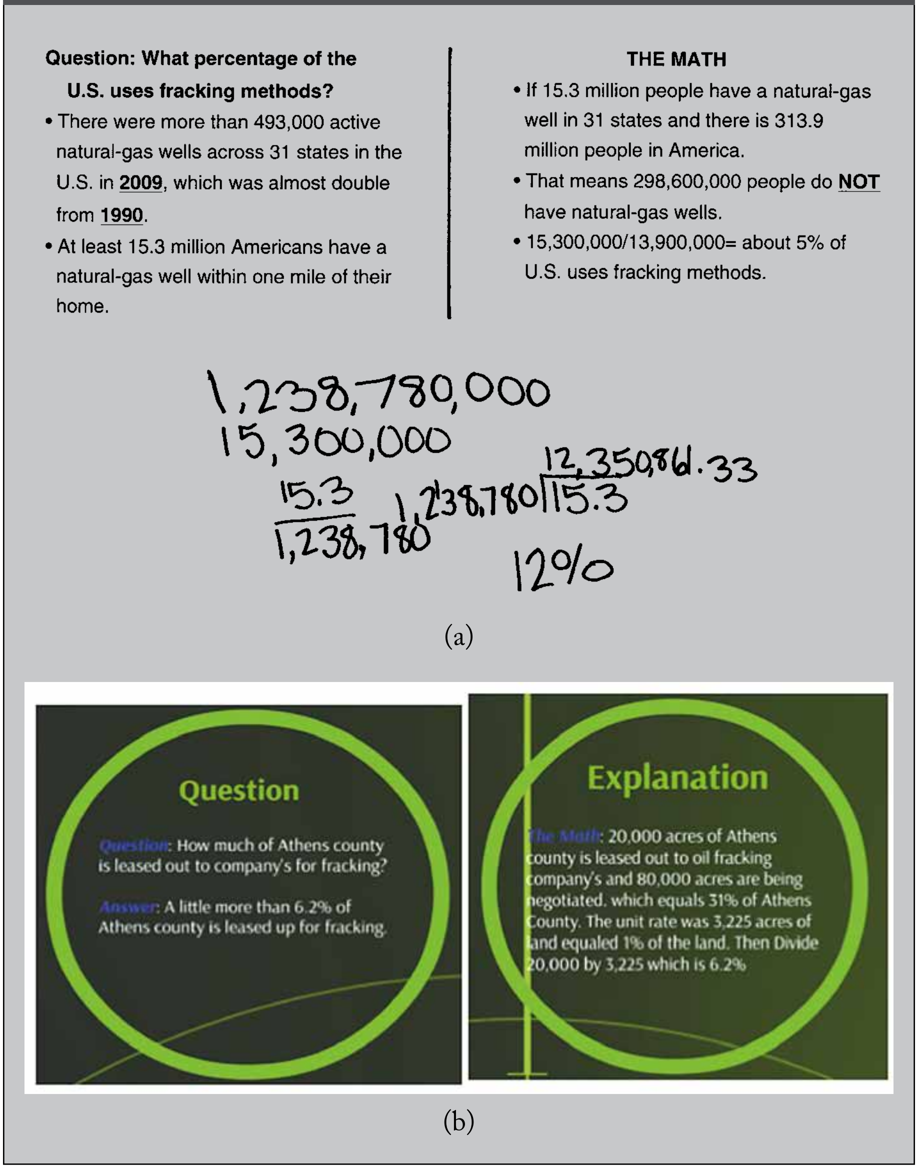
Some students who had difficulty finding information about fracking for natural gas chose to explore fracking for oil. Other students modified their questions in different ways. For example, one student originally asked about the increase of fracking in Ohio. When he was unable to find the answer using Ohio data, he looked at national data. Another student asked, "How do they measure the right amount of fracking fluid to break up the rock?" She found that the amount could vary. However, in the process of gathering her research, she also learned that 70 percent of the fracking fluid can leak underground if it is not controlled. This intrigued her, so she calculated the amount of fluid that would be lost underground in the United States if it was not controlled. This led to a discussion about how the companies control leakage, and whether or not her estimate was accurate.

Several students wanted to explore the prevalence of fracking in the United States. Since this topic could be interpreted in a variety of ways, students had to decide how to represent the problem. Many students answered the question differently. Some decided that they would find the percentage of states that allow fracking. Another student found the total number of people who lived near a fracking well, and I encouraged her to make sense of the number by comparing it with the population of the United States (see **fig. 2a**). Another student, who looked at local data, found the number of acres countywide that had been leased (see **fig. 2b**).

ENCOURAGING HIGH-LEVEL MATHEMATICS

Because the goal of my lesson was for students to use math as a tool to model

Fig. 2 One student's slide explored the mathematics of natural gas in America (a); another student looked at county leasing percentages (b).



a real-world situation, I decided that the students could use basic mathematics if the best model necessitated simple calculations. However, the fracking lesson followed a unit on multistep percentage problems and proportional reasoning, so I encouraged students to use their new skills to describe the situations they were exploring.

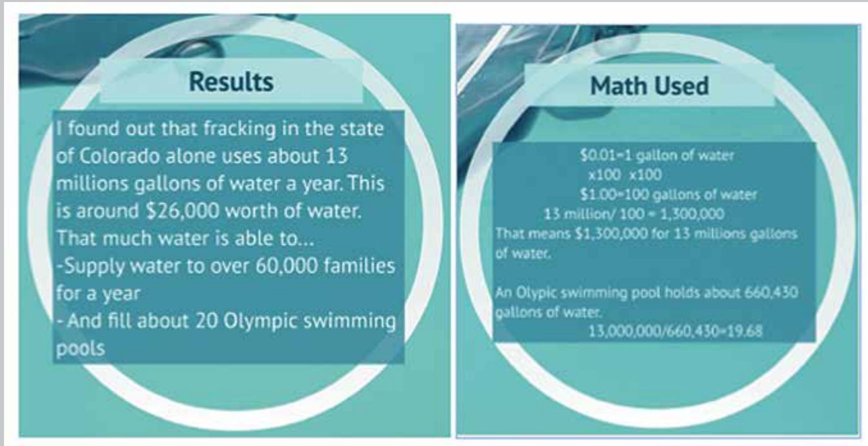
One common struggle experienced by students was how to create the mathematical model. Many students showed me the information they found and said, "I didn't use any math." In those cases, I asked questions to encourage the use of mathematics, such as, "That number is really big, and it doesn't quite make sense to me. How could you relate that to something we see every day?" or "How can you combine that information to give me the whole picture?"

Many students were able to find data at two points in time, and some of these students realized that they could calculate the percentage change. Students who did not remember how to find a percentage change needed the prompt, "How can you represent the size of that increase?" Other students used multiplication or addition to calculate large numbers. I introduced these students to scientific notation as a way to write very large numbers. For example, some students converted millions of gallons of water into Olympic-size swimming pools. One student explained that it was difficult to visualize 13 million of anything, but 20 Olympic-size swimming pools were easier to comprehend (see **fig. 3a**). These methods helped students make sense of and communicate the size of very large numbers.

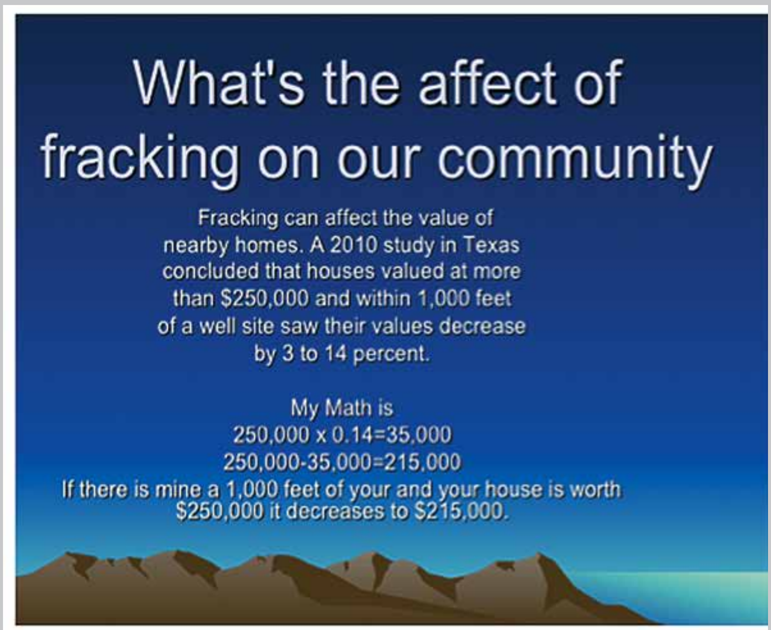
Some students found a numerical answer from a website that answered their question directly. I asked what they could do with that information. These students were often given a percentage, so they worked backward to find the raw numbers. One student found from one source that 30 percent of wastewater resurfaces; another source stated that this amount correlates to 1.3 billion gallons of water. I asked her if she could use that information to calculate how much water was pumped underground: "If you know what 30 percent represents, then what was 100 percent?" Another student found that the values of homes located near wells decreased by 3 to 14 percent. The student calculated the new value of the home (see **fig. 3b**).

Occasionally students needed suggestions regarding what missing piece of information to find. One student, who wanted to find how many U.S. wells were being used, could not find the answer. She was able to find the amount of water used in 2011, so I suggested that if she investigated the amount of water used in one well,

Fig. 3 Examples of students' real-world analyses included water usage compared with an Olympic swimming pool (a) and the effect of fracking on home values (b).



(a)



(b)

then she could use both pieces of information to determine the number of times that fracking occurred that year.

SHARING AND DISCUSSING

On the last day of the lesson, students shared their presentation slides with the class. A few students who had difficulty answering their questions described the decisions they made. Some students acknowledged that their models were not perfect. One student averaged the profits made by oil and gas companies, but stated, "There is no real answer" because the three values he found were very different.

Students asked one another questions about their models, which required that presenters justify their decision making, such as why they chose to report the effects of fracking for oil rather than natural gas. One student chose to use the highest percent in a range to calculate an amount, and the class asked why he chose that number rather than the lowest or the median.

The students then completed a written reflection on fracking, what they learned about fracking in math class, and how math can help people understand the world:

> You can use numbers to better understand situations that can't be expressed in words.
>
> If you want to know a statistic that you can't Google™, you must calculate it.
>
> You can decide what is going on to make better choices.
>
> It can help them solve things that they don't know using information they do know.

Several students also related their answer to the math that they did during the project. For example, one student who looked at solar panels and solar energy said that math can help you "solve" problems like fracking. Students who compared the amount of water used in fracking with the water used by one household explained that math can help you make comparisons to understand things better.

SUMMARIZING THE MODELING PROCESS

During the lesson, students made mathematical decisions. They chose a question to investigate, sifted through information on the Internet, and decided what and how to use the information to create their mathematical model. They also had to think about the mathematics they used and what each number and procedure meant in terms of the context. Finally, when creating their presentation slides, students had to decide what information was important to include about their mathematical process. Although some struggled with the mathematical model, the result was a more enriching mathematical experience.

REFERENCES

Common Core State Standards Initiative (CCSSI). 2010. Common Core State Standards for Mathematics. Washington, DC: National Governors Association Center for Best Practices and the Council of Chief State School Officers. http://www.corestandards.org/wp-content/uploads/Math_Standards.pdf

Corbett, Michael. 2007. *Learning to Leave: The Irony of Schooling in a Coastal Community.* Halifax: Fernwood Publishing.

Gutstein, Eric, and Bob Peterson. 2005. *Rethinking Mathematics: Teaching Social Justice by the Numbers.* Milwaukee, WI: Rethinking Schools.

Hunt, Spencer. 2012, March 12. " 'Fracking' Payoffs Luring Local Officials." *The Columbus Dispatch.* http://www.dispatch.com/content/stories/local/2012/03/12/fracking-payoffs-luring-local-officials.html

Lesh, Richard, and Judith Zawojewski. 2007. "Problem Solving and Modeling." In *Second Handbook of Research on Mathematics Teaching and Learning,* edited by Frank K. Lester Jr., pp. 763–804. Charlotte, NC: Information Age Publishing.

Piaget, Jean. 1976. *The Child and Reality.* New York: Penguin Books.

Smith, Terry. 2013, March 13. "Do New Oil and Gas Maps Put Athens Back in Play?" *The Athens News.* http://www.athensnews.com/ohio/print-article-39264-print.html

Smith, Yves. 2012, July 24. "Doing Some Math on Fracking Propaganda." Naked Capitalism. http://www.nakedcapitalism.com/2012/07/doing-some-math-on-fracking-propaganda.html

Vithal, Renuka. 2003. *In Search of a Pedagogy of Conflict and Dialogue for Mathematics Education.* Dordrecht: Kluwer Academic Publishers.

CCSSM Practices in Action

SMP 4: Model with mathematics
Standard 7.RP.2: Recognize and represent proportional relationships between quantities
Standard 6.EE.9: Use variables to represent two quantities in a real-world problem that change in relationship to one another

Any thoughts on this article? Send an email to ***mtms@nctm.org.***—*Ed.*

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