

September 11, 2006

Dear Harvard Schools Trust,

I would like to reiterate how much I appreciate your support of my mini-unit on the play Proof. My students seemed to really enjoy such a non-traditional lesson in mathematics and the play provided a refreshing context for classroom interaction. I am looking forward to sharing the play with this year's group of students.

This summer I wrote and submitted an article on the Proof mini-unit to the National Council of Teachers of Mathematics magazine Mathematics Teacher. The article is still in the review process, but I have attached it as "proof" of this experience and so that you may read for yourself about the actual implementation of the unit.

Thank you for making this experience possible.

Sincerely,
Julie

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"WE ALL USE MATH EVERY DAY... to forecast weather, to handle money...
We also use math to analyze crime, to reveal patterns, to predict behavior..."

Reading the play *Proof* in math class

Julie Raye Horton

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The Pulitzer Prize winning play *Proof* by David Auburn offers lessons in mathematics, mathematicians, and the search for independence and individuality. This article describes how the play was used in a 9th grade mathematics classroom to help meet standards for school mathematics (NCTM 2000), to develop connections across disciplines, and to foster the appreciation of the culture of mathematics.

I believe one of my responsibilities as a 9th grade math teacher is to introduce my students to the culture of mathematics. These cultural connections are crucial if students are to meet the national standards of mathematics education. By reading, watching, and laughing at mathematics in books, on television and in movies, students are able to “recognize and apply mathematics in contexts outside of mathematics” and “analyze and evaluate the mathematical thinking” (NCTM 2000). By discussing what they watch and read, they improve their ability to “communicate their mathematical thinking coherently and clearly (NCTM 2000).” Often these skills are developed and enhanced without the students even realizing that they are learning. I may be one of the few Math Geeks in my students’ lives, someone that truly loves math and takes special interest when mathematics and popular culture collide. If I don’t point out these collisions to my students, perhaps no one will, and these cultural connections will go unutilized. For this reason, in my classes this year we read the Pulitzer Prize winning play *Proof* by David Auburn (2001).

Proof centers around Catherine, a math student in her 20’s. Catherine has recently lost her father, a brilliant mathematician who suffered from mental illness. Catherine wants to follow along in her father’s mathematical footsteps and hopes she has inherited his genius. At the same time, she fears a genetic link to his mental instability and worries that she might suffer from his illness. As my 9th graders begin their struggle to find their own independent identities, they can relate to Catherine. They too want to be like their parents in some ways,

and desperately hope for disparity in others. Moreover, as budding mathematicians, they can learn about the mathematics outlined in the play; be exposed to the trials of mathematical research as Catherine and other characters discuss *Proofs*, theses, and journal articles; and laugh knowingly at the math jokes.

I read *Proof* for the first time as a mathematics graduate student. I loved the sarcasm and wit of the characters and related to the universal themes of the story; moreover, I enjoyed the feeling of comradery from reading about other mathematicians. Once I became a classroom teacher, I decided I wanted to share the play with my students.

I'll be Catherine or Claire, whoever is the sarcastic one.

To introduce the unit, I explained that for the next week or so, we'd journey outside the realm of traditional math class activities and read a play. I described *Proof* as not only a Pulitzer Prize winning work of literature, but as one with mathematical connections and themes to which I hoped they could relate. Finally, to appeal to their 9th grade sensibilities, I mentioned the sarcasm, banter, and colorful language.

On the whiteboard was the question "In what ways do you hope you are like your Mom or Dad? In what ways do you hope you are different?" I asked my students to think about the questions and write their responses on a piece of

paper (not to be turned in). After 5 or 10 minutes, I asked students to share their answers. One of the more poignant responses was from a male student who wants to be able to cook like his father, but doesn't want to struggle with the same weight issues. After our discussion, I explained that Catherine, the main character in *Proof*, struggles with those same questions in the course of the play.

We read the play as a class, with students volunteering to take different roles. I had arranged our tables in a large rectangle so that we could all see each other, an idea borrowed from a colleague who teaches English. In some classes, there were many volunteers, even offers to read across gender lines. In other classes, I had to plead with students. It was interesting to note that the classes, and individual students, that were most engaged and enthusiastic about the play were often not usual contributors to classroom discussions about math problems and exercises. As the students read, I watched them, trying to assess their engagement. With few exceptions, students were quiet and respectful and followed along in their books as we read. They laughed at the "right" times and asked questions when they were confused. When we began reading each day, they were able to explain where we left off and summarize the previous events.

At appropriate times in the play, we discussed the plot and the content. A big question as the story progresses is "Do you believe Catherine? Or is she suffering from mental illness as her father did?" We returned to that question again and again, but we also answered such questions as "Is Claire just a bossy

big sister, or does she have reason to act that way?" and "Why is it especially awful that Hal just did that?" The timeline in *Proof* can be confusing, as there are several flashbacks, so we also talked about when events took place relative to other events.

At one point in the play, Catherine mentions Sophie Germain, a famous French mathematician, and Germain primes, one of her discoveries. As part of my lesson plan, I had created a worksheet on Germain primes, asking students to explain what they were and create a list of some of them. While I feel that it is important to expand on the mathematical content in *Proof* (I am, after all, a teacher of mathematics.), this was the least successful component of the unit. Based on my student evaluations of the lesson, they agree; some suggested changes to the unit include "explaining Germain primes a bit more" and incorporating "more involved math". One of my goals for improving and tweaking this lesson is to develop a more engaging and relevant way to elaborate on the discoveries of Sophie Germain.

Why are two of your students wearing bathrobes?

Two activities concluded the *Proof* unit. For the first activity I divided the class randomly into groups of 3 or 4 and gave them a list of questions soliciting their opinions on topics raised in the play, either about storylines or characters in the play or about tangential issues. They were to exchange email addresses and

email a one-paragraph response to one of the questions to their group. In addition, they were to respond to two of the answers sent by their groupmates. I asked that I be included in each group so that I could "eavesdrop" on the conversations. I hoped that the email forum would allow students to communicate with each other more freely and via a media with which they feel comfortable, and the responses indicated that this was true.

Some of the most insightful conversations were about Sophie Germain and whether her contributions to the field of mathematics were more amazing because she was a woman and thus had to overcome societal obstacles in addition to mathematical ones; most disagreed. As one student asked, "If a woman in our time had discovered such a thing, would it be considered amazing (simply because she was female)?" Another pointed out, "The amazing aspect of her accomplishments wasn't particularly the fact that she was a woman and that she figured it out, which are both great, but the fact that she did it 'against the odds.' Sophie Germain's achievements should not be treated as 'more amazing' simply because she is a woman, but simply as an amazing achievement where the issue of gender is not apparent."

The goal of the second activity was to tap into the creativity of my students. They were to create a project, in small groups, or individually, from a list of choices. These options included writing a review of a performance of the play (pretending they had seen it), creating a program cover for a performance, sketching three of the characters, and acting out part of a scene in front of the

class. The students were given a rubric defining the grading scheme for this project, which was based mainly on effort evident. Any student who turned in a project earned at least a C. Most of my students designed program covers, but a few turned in beautiful character sketches. One of my favorite moments from the unit was the performance of a “morning after” scene by two bathroom-clad male students, ignoring gender roles.

Finally, we watched the movie version of *Proof*, which was released in 2005 and stars Gwyneth Paltrow, Anthony Hopkins, and Jake Gyllenhaal. We discussed what had been changed from the play to the movie, how the movie compared to their vision while reading the play, and which actors they would have cast in the movie. Students gained perspective from SEEING the play, in addition to reading it, and many suggested it might be better to alternately read and watch scenes. While a very valid suggestion, this might be impossible as the play was slightly rearranged to create the screenplay.

Like, it’s, you know, a proof.

I purposefully designed this mini-unit with the needs of all of my students in mind. We read the play in class so that students could read the play aloud, follow along silently in their books, or just listen to the dialogue. We discussed the plot frequently to enforce understanding. In one of my classes, we worked on the projects and email discussion questions in class to insure that the tasks

would be completed and the guidelines would be followed. I included many options for the project so that students could showcase diverse talents.

The interest of some of my students surprised and impressed me. Some students who never showed enthusiasm in class became very involved. In particular, one student decided at the very beginning of the unit that, since his middle name is the name of one of the characters, that role was his to read. When that character was not in a scene, he volunteered to read other parts. His active participation in the reading led to very thoughtful work throughout the unit. Another student, who rarely speaks in class, even to his classmates, was also a frequent volunteer. When projects were due, some students chose to act out a scene and showcase surprising talents; a female student capitalized on her outgoing personality and unique style by giving Catherine a Valley-Girl twist, and her classmate belied his usual disdain for classroom activities by embodying his role and showing his flair for acting.

Improving your creative writing; it's not just for English class anymore.

The student response to the unit indicates that they appreciated the change of pace and that they did learn from reading and discussing the play. Students especially liked *Proof* as a catalyst for class discussion; as one student wrote in her evaluation of the unit, "The best part was hearing other people's thoughts while reading aloud." Another praised "being able to interact with

everyone in the class.” Other students liked “being able to read a story and have it relate to math.” The same student noted that it was “nice to learn in a different style.”

Most of the lessons that students took away from the play were expected and intended consequences of my unit design. However, several surprised and delighted me. One student, a promising writer, noted that “readers become more engaged if you teach them something in your work;” she learned a strategy to improve her own writing, *in math class*. Another student claimed to have gained “insight into the mathematician world”, especially relating to “male vs. female”. Several students mentioned learning “the importance of trust”; in particular one student gave the advice, “trust your own work.” I am pleased that my students now know about Sophie Germain and her work with prime numbers and better understand how mathematicians do their work, but these surprise lessons are the most gratifying.

Moreover, the parent feedback about the project has been very positive. I was fortunate enough to receive a grant from an organization within my district whose mission includes providing materials to enhance our curriculum. The parents and community members involved with this organization could not have been more receptive to the project. As the organization president wrote to me upon the submission of my grant proposal, “Your materials made me excited about the project—what an interesting class to participate in.”

A final thought from the Math Geek

In the *Teaching Mathematics in the Middle School* focus issue on mathematics and literature, Jennifer Bay-Williams (2005) and Betsy McShea, Judith Vogel, and Maureen Yarnevich (2005) recommend making mathematical connections to books our students are already reading. It is just as important to introduce our students to books with connections to mathematics or mathematicians. These works of literature can provide our students with mathematical role models who are not that different from them. This unit was successful, I think, in part due to the fact that my students could relate and empathize with Catherine and the other characters. They may have been Math Geeks, but as Hal says in the play, "But they're geeks who, you know, ... sort of make you question the whole set of terms: geek, nerd... (Auburn 2001, p. 16)"

References

Auburn, David. *Proof*. New York: Faber and Faber, 2001.

Bay-Williams, Jennifer M. "Poetry in Motion: Using Shel Silverstein's Works to Engage Students in Mathematics." *Teaching Mathematics in the Middle School* 10 (April 2005): 386-393.

McShea, Betsy, Judith Vogel and Maureen Yarnevich. "Harry Potter and the Magic of Mathematics." *Teaching Mathematics in the Middle School* 10 (April 2005): 408-414.

National Council of Teachers of Mathematics (NCTM). *Principles and Standards for School Mathematics*. Reston, Va.: NCTM, 2000.

Essential Questions	NCTM <i>Standards</i> (NCTM, 2000)	Activities
<p>In what ways do you hope you are like your Mom or Dad?</p> <p>In what ways do you hope you are different?</p>		<p>Individual brainstorm; Class discussion; Email discussion</p>
<p>What are Germain primes?</p> <p>Who was Sophie Germain?</p> <p>Was her work more remarkable because she was a woman?</p>	<p>Number & Operations</p> <ul style="list-style-type: none"> • use number-theory arguments to justify relationships involving whole numbers <p>Communications</p> <ul style="list-style-type: none"> • communicate their mathematical thinking coherently and clearly to peers, teachers, and others • analyze and evaluate the mathematical thinking and strategies of others <p>Reasoning and Proof</p> <ul style="list-style-type: none"> • recognize reasoning and proof as fundamental aspects of mathematics <p>Problem Solving</p> <ul style="list-style-type: none"> • monitor and reflect on the process of mathematical problem solving 	<p>Class discussion; Worksheet; Email discussion</p>
<p>How is mathematics used as a vehicle for humor in the play?</p>	<p>Connections</p> <ul style="list-style-type: none"> • recognize and apply mathematics in contexts outside of mathematics <p>Communications</p> <ul style="list-style-type: none"> • communicate their mathematical thinking coherently and clearly to peers, teachers, and others 	<p>Class discussion</p>
<p>What is math research like?</p>	<p>Connections</p> <ul style="list-style-type: none"> • understand how mathematical ideas interconnect and build on one another to produce a coherent whole <p>Reasoning and Proof</p> <ul style="list-style-type: none"> • recognize reasoning and proof as fundamental aspects of mathematics 	<p>Class discussion; Show & tell</p>
<p>How do envision the play?</p> <p>What would you do if you were involved in the production?</p> <p>Who would you cast in the movie?</p>		<p>Project; Class discussion; Email discussion</p>