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Reading Can Expand What Kids Think About Mathematics

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I love reading about math. Not dry textbooks, but texts that bring to life the people who do math as a profession. Or texts that introduce strange or unexpected ideas in ingenious ways and leave my heart pounding. Or texts that make me think about mathematics and mathematicians differently. In the past few years, I have started to use them with my students in small ways. I didn't want students to leave high school thinking mathematics is only what's in their high school curriculum. It's so much more. Math involves people… and big and tough ideas… and surprise and defeat and complex emotions. And different mathematical ideas exist in different times and places.

I've hosted regular formal book clubs with an entire class and also arranged informal book clubs with kids who were interested in expanding their horizons. Occasionally, I'll meet one-on-one with a student to do an independent study around a book, or simply recommend a book for a student to read and then we can discuss. There are *so many* interesting mathematical texts out there that teachers can use to draw in students. I've found all you have to do is "sell it" well. With that in mind, I'll try to sell a handful of texts that I've used with students or am hankering to try out. If you read anything about math

and enjoy it, take a moment to think if there's a student or three (or even a whole class) who might enjoy reading and chatting about it. If so, bring iced tea and donuts to your book club, and forge a new type of relationship with some of your kids.

1. *Flatland: A Romance in Many Dimensions* by Edwin A. Abbott

"An unspeakable horror seized me. There was a darkness; then a dizzy, sickening sensation of sight that was not like seeing; I saw a Line that was no Line; Space that was not Space: I was myself, and not myself. When I could find voice, I shrieked aloud in agony, 'Either this is madness or it is Hell.' 'It is neither,' calmly replied the voice of the Sphere, 'it is Knowledge; it is Three Dimensions: open your eye once again and try to look steadily.'"

A mere 96 pages, this Victorian satire tells the story of a square (named "A. Square"), a two-dimensional creature who lives in a plane called Flatland. The first half of the book outlines the hierarchy of the society (and raises questions about equity and power) while the second half of the book plucks A. Square out of his flat world to explore a one dimensional dream world (lineland) and a three dimensional world (spaceland). Kids I've read this with start to believe that there could be four (or five, or six) spatial dimensions just like A. Square does, when before reading the book, they always claim there are only three spatial dimensions (the x-dimension, the y-dimension, and the z-dimension) and that a fourth spatial dimension is ridiculous. We have lots of fun unpacking that. They also love discussing issues around equity and social justice which arise because of Flatland's social order (which in some ways parallels our own social order).

Suggested readers: Although I think that the book would work at the high school level and involves many geometric ideas, I'd argue the book is most appropriate for 11th and 12th graders. (As an added bonus, there is an enjoyable animated movie released in 2007 based on the book, with voices by Martin Sheen and Kristen Bell.)

2. *The Calculus of Friendship* by Steven Strogatz

"I was 15 when I took calculus from Mr. Joffray. One thing about him was unlike any other teacher I'd ever had: he worshipped some of his former students. He'd tell stories about them, legends that made them sound like Olympian figures, gods of mathematics."

This is a beautiful little book that any calculus teacher could use in their classes, having students read chapters throughout the year, or reading it all at once at the end of the year after an Advanced Placement exam. Steven Strogatz is now a world-famous mathematician at Cornell, but at one point, he was a high school student who had Mr.

Joffray as a teacher. For decades after graduating, Strogatz and Joffray wrote letters to each other sharing fascinating mathematical discoveries and personal triumphs and losses. The autobiographical book with an interesting structure includes some of the letters Strogatz uses to illuminate their evolving relationship, letting the reader share in the emotionally transformative journey from student to teacher and teacher to student.

Suggested readers: The book would work well for any calculus student. The text is written conversationally and exchanges about calculus, mentorship, life in college, teaching, and the student-teacher relationship will spontaneously arise in discussion. One of my students wrote her own math autobiography (https://samjshah.com/2017/06/16/the-friendship-of-calculus-a-girls-journey-into-the-unwavering-depths-of-the-third-dimension/) after reading this book, and it is something I will treasure forever.

Bonus book: Strogatz has also written *The Joy of X: A Guided Tour of Math, from One to Infinity*. This book has very short chapters, each illuminating interesting aspects of mathematics for a general audience. How mathematicians "count" infinity, using mattresses to introduce group theory, and even understanding the basic concepts behind calculus; these are ideas that Strogatz illuminates for everybody. This book is useful for any high school math class and most chapters would be accessible to middle school students.

3. *How Not To Be Wrong: The Power of Mathematical Thinking* by Jordan Ellenberg

"On July 12, 2005, the Compliance Unit of the Massachusetts State Lottery received an unusual phone call from an employee at a Star Market in Cambridge, the northern suburb of Boston that houses both Harvard and MIT. A college student had come into the supermarket to buy tickets for the state's new Cash WinFall game. That wasn't strange. What was unusual was the size the order; the student had presented fourteen thousand order slips, each one filled out by hand, for a total of $28,000 in lottery tickets."

Reading this book made me *wish* I taught statistics so that I could discuss chapters from this book with students. Through compelling examples from the real world, like how Facebook can make conclusions about us from limited data or how the lottery has been scammed, challenging and counterintuitive statistical ideas come alive. Although I have never read this with a group of students, I have had students independently read and love parts of this book based on my recommendation. Although this book doesn't require too much calculational work, it does draw stunning but nuanced arguments.

Suggested readers: Reading the book (or chapters) would work best for students who are in a full year statistics course.

4. *The Number Devil: A Mathematical Adventure* by Hans Magnus Enzensberger

"'A fraction!' Robert cried. 'A fraction that never ends, a fraction so grotesque it hurts my eyes to look at it! I hate fractions! Mr. Bockel loves them. He loves to torture us with them. Get that monster out of my sight. Please!'"

I stumbled across this book because a math-loving student of mine years ago told me it was one of his favorite childhood books. And after reading it, I understood why. Anyone who knows the tiniest bit of mathematics (like addition or multiplication) will journey along with Robert as he starts talking with a number devil -- and along the way, will see a wider world of mathematics come to life through an absorbing story and great visuals. Some of the math ideas introduced are the Fibonacci numbers, Pascal's triangle, prime numbers, square numbers, triangular numbers, and infinite series.

Suggested readers: I can see this being a wonderful read in a book club in a 7th or 8th grade class, or even in an Algebra II or Precalculus class.

5. "The Paradox of Proof" by Caroline Chen (online here (http://projectwordsworth.com/the-paradox-of-the-proof/))

"On August 31, 2012, Japanese mathematician Shinichi Mochizuki posted four papers on the Internet. The titles were inscrutable. The volume was daunting: 512 pages in total. The claim was audacious: he said he had proved the ABC Conjecture, a famed, beguilingly simple number theory problem that had stumped mathematicians for decades. Then Mochizuki walked away."

A Japanese mathematician proposed a solution to a long-unsolved problem. The problem was that the mathematics world simply didn't understand his work. This article which can be read fairly quickly lays out a mathematical saga that is *currently* happening and raises important questions about mathematics. If a proof is written but isn't understood by other mathematicians, do we consider that question answered? If not, then is all mathematical knowledge socially constructed? At the heart of this article are questions about what makes something true (and who gets to decide), why we need to communicate our mathematical ideas clearly to others, and what obligations mathematicians have to each other. When reading this, students get enchanted by the idea that a tough problem might have been solved but we just don't know. And as they

start thinking about this, they learn a bit about the ABC conjecture (that ties together addition and multiplication), and they start talking about the nature of truth. And best of all, after talking about this article, my kids understand why I insist on having them craft clear mathematical explanations in their solutions.

Suggested readers: Although this article would work well in any high school level class, I would recommend it be used in any course that requires a lot of mathematical writing or involves students developing proofs (like in geometry).

6. *Measurement* by Paul Lockhart

"I'm going to assume that you love beautiful things and are curious to learn about them. The only things you will need on this journey are common sense and simple human curiosity. So relax. Art is to be enjoyed, and this is an art book."

Paul Lockhart is our guide through many unexpected, beautiful, stunning mathematical ideas. These are all ideas that come up in geometry, algebra, or calculus, but even after teaching for over a decade, many of the approaches he takes and some of the conclusions he draws were new and exciting to me. I loved the discussion my class had based on an excerpt I gave them which contrasted "physical reality" and "mathematical reality," a mind-blowing experience for many of my students.

Suggested readers: This book actually illustrates mathematical content, so excerpts from Part One ("Size and Shape") could easily be used in a geometry class to illuminate a variety of ideas (especially scaling and proportion), and there is a stunning section for a precalculus class on conic sections which almost made me weep at the beauty. All of Part Two ("Time and Space") outlines the fundamental ideas of calculus in an innovative way. I would love for a student in precalculus to ask me, "What is the calculus thing?" so I could do an informal independent study with them on the 100 pages in Part Two.

7. *The Man Who Knew Infinity* by Robert Kanigel "For Hardy, Ramanujan's pages of theorems were like an alien forest whose trees were familiar enough to call trees, yet so strange they for seemed to have come from another planet; it was the strangeness of Ramanujan's theorems that struck him first, not their brilliance. The Indian, he supposed, was just another crank."

Although lengthy at over 400 pages, this beautifully written and carefully researched biography of mathematical wonder Srinavasa Ramanujan brings early twentieth century India and England alive. We follow an Indian clerk (Ramanujan) and pre-eminent

Cambridge University mathematician (G.H. Hardy) as they forge their relationship and both become icons in the history of mathematics. Although students will be exposed to clearly written mathematical ideas of Ramanujan that deal with infinite series and prime numbers, it isn't the mathematics in this book that stand out. It is how *embedded* Ramanujan and Hardy are in their cultural, political, and social settings. Mathematics isn't done in a vacuum, and following the life of Ramanujan and Hardy really emphasizes how *human* an endeavor the practice of mathematics is. The students I'm reading this with love discussing history and religion, and have seen how this book matches up with a lot of what they've learned in other classes with a more humanistic bent. This book also has a major motion picture (of the same name) starring Dev Patel which I can't wait to watch with my kids after we finish reading this.

Suggested readers: I'm reading this with some precalculus students now, and conversations about religion, the notion of "genius," and questions about who gets to do mathematics have come up naturally.

Bonus book: As a side note, I have read G.H. Hardy's famed treatise *A Mathematician's Apology* with students. Written at the end of his life, Hardy muses on why a mathematician's life is important and worthwhile. It doesn't introduce the reader to many mathematical ideas, but instead takes a philosophical argument to why mathematics matters. It is a bit dense, so I would recommend reading this with juniors and seniors. But it is also polemical, which leads to interesting debates and discussions.

8. "Mathematics for Human Flourishing" by Francis Su (online here (https://mathyawp.wordpress.com/2017/01/08/mathematics-for-human-flourishing/))

"So if you asked me: why do mathematics? I would say: mathematics helps people flourish. Mathematics is for human flourishing."

I realize the need to actively seek out diversity in my texts. All of the writers and main characters in the texts I've compiled are about men, usually white men. My overstuffed bookshelf devoted to math books follows this trend. Where are the women? The mathematicians of color? I also worry about sharing texts with students which perpetuate the myth that success in mathematics can only be achieved by someone who is born a "genius." That is why I am grateful that I stumbled across a transcript of mathematician Francis Su's keynote address at a conference in 2017. He takes on the same question that G.H. Hardy wrestles with *A Mathematician's Apology* but provides a more current, broad, and uplifting response. Importantly, his response addresses

diversity in mathematics. This beautiful speech resonates with students and teachers alike. And there are so many sentiments to be mined and unpacked by students in a discussion of the text.

Suggested readers: Any teacher of high schoolers who wants to answer the question of "why do we have to learn this" (where "this" is any topic in the curriculum) could address that by reading and then having an insightful conversation about this speech.

Sameer Shah is in his eleventh year of teaching math in Brooklyn, NY. He has been writing a blog about his thoughts about teaching math from the very beginning (www.samjshah.com (http://www.samjshah.com/)) and loves crafting his own curricular materials. His favorite things currently include watching mindless TV, brunching with friends, reading books, and geeking out about math teaching. Not necessarily in that order... but sometimes in that order.

SAM SHAH
Math Teacher

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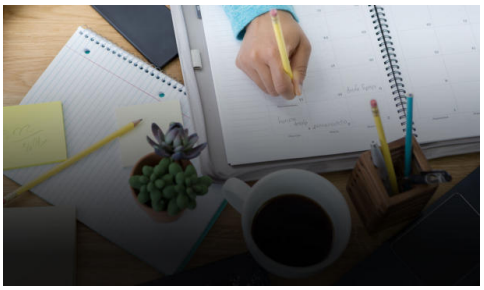

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