Women and Minorities in Mathematics

Incorporating Their Mathematical Achievements Into School Classrooms

Evelyn Boyd Granville: Complex Solutions to Real-Life Problems

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Evelyn Boyd Granville in 2001

In 1949 Evelyn Boyd Granville became the second black woman we know of to earn a Ph.D. in mathematics. Granville is well known for examining diverse and complex solutions to real-life problems - quite literally, as her doctoral work was in the field of complex analysis, but this theme can also be found in her approach to life and in her teaching philosophy. Over the course of her career, she worked for NASA and others in support of space missions, and then she transitioned to college teaching, where she focused on the mathematics education of future teachers. Today she continues to speak as an advocate for mathematics. Granville advises that:

> *Life is best lived when you try to leave the world in better shape.* (Smith, 2007)

By applying Granville's own definition to her efforts to make the world better, it is easy to see that Granville has led a rich and wonderful life.

First Black Women Mathematicians

The earliest black women who studied mathematics faced many barriers:

> *Over the years, black women who might be disposed to pursue a career in mathematics faced the "double whammy" of racism and sexism. Like blacks, women were not considered to have the mental skills necessary for advanced mathematical inquiry. For all women, and especially for black women, the field of mathematics was essentially shut tight.* (The Journal of Blacks in Higher Education, 2001)

Martha Euphemia Lofton Haynes

In 1943 Martha Euphemia Lofton Haynes (1890-1980) became the first black woman we know of to conquer the race and sex barriers at the Ph.D. level in mathematics. She earned her Ph.D. from Catholic University and then she had a distinguished career in Washington, DC. She taught in the public schools for forty-seven years and she occasionally taught part time at Howard University. Her husband was a deputy superintendent of public schools. After her retirement she chaired the DC Board of Education, where she had a central role in the integration of DC public schools. In 1976, she reflected:


Martha Euphemia Lofton Haynes ca. 1900-1910

> *I have been a mathematics scholar all my life, through high school,*

> *through college, and then to get my doctor's degree in mathematics…. I didn't expect to get my doctor's degree, never, in mathematics, but I wasn't surprised in other areas because I enjoyed it so much.* (Kenschaft, 2005)

Evelyn Boyd Granville

Evelyn Boyd Granville also grew up in Washington, DC. She was born on May 1, 1924. Haynes' successful efforts to desegregate the DC public schools came much later, so it is not surprising that Granville attended a segregated high school. The school was excellent and Granville feels that this was due to teacher training and dedication:

> *Although the systems were separate, the colored system was in no way inferior to its counterpart. The system achieved a national reputation for excellence because teachers and administrators were well trained in their subject areas and were dedicated to providing the kind of education that students needed to be able to compete in a larger community.* (Case & Leggett, 2005)

Inspired by her high school teachers and with the encouragement of her mother and aunt, she graduated as valedictorian of her class, and then received a partial scholarship to attend Smith College. Her mother and aunt made many sacrifices in order to help her make up the difference between her scholarship and her bills (Kenschaft, 1981). Granville earned degrees in mathematics and physics from Smith. She earned her Ph.D. from Yale University in 1949, becoming the second black woman we know of to obtain a doctorate in mathematics.

Granville spent a year at a research postdoctoral position. She then interviewed for jobs but she encountered discrimination. At one school, she later found out, when the hiring committee discovered that she was black, "they just laughed" and the dean said they "would have to change the plumbing" (Murray, 2000). At the national level, she advocated for the integration of mathematics conferences and she was an outspoken critic of discrimination (Inniss and Bozeman, 2006). She accepted a position at Fisk University, a historically black institution, but after two years at Fisk, she moved to jobs in government and industry, which offered more opportunities. She used numerical analysis to aid in the design of missile fuses and she later worked on trajectory and orbit analyses for the Vanguard, Mercury, and Apollo space projects:

> *I found employment in government and private industry, where I had to study on my own areas of mathematics (mainly numerical analysis) needed to do the projects assigned to me. Whenever I speak to groups of young people I always advise them that learning never ends. The projects I worked on were in no way related to my thesis topic.* (Granville, 2007)

In 1960 Granville married Reverend Gamaliel Mansfield Collins. After her first marriage ended in divorce, Granville returned to the academic world in 1967 to concentrate on teaching:

> *How do you teach the beauty of mathematics, how do we teach them to... solve problems, to acquaint them with various strategies of problem solving so they can take these skills into any level of mathematics? That's the dilemma we face*. (O'Connor & Robertson, 2001)

She married again in 1970, to Edward V. Granville, a real estate broker, and has remained happily married.

She has received numerous honors and awards, including an honor from the National Academy of Sciences in 1999. Granville has retired a number of different times, but she still visits schools and universities, and seems to be drawn to continue her efforts to show students the beauty of mathematics. In the summer of 2007, she taught a "Math Warm-Up" class for students entering grades 6-7 (Granville, 2007). Just as Granville was inspired by her teachers, she continues to inspire students.

Changing Conditions for Black Women

Conditions began to change as black women obtained doctorates in mathematics, making it easier for others who followed, but there is still much work to be done. As of 1999, it was estimated that there were only 40 total African American women who had earned doctorates in mathematics, and only 20 more black women mathematicians elsewhere in the world (Kenschaft, 1999). More recent data is not available due to an increased emphasis on privacy issues.

Activities and NCTM Standards

The following activities relate to Evelyn Boyd Granville and address numerous points in the NCTM *Principles and Standards for School Mathematics*.

Activities Related to her Thesis Work

Granville says that her thesis was not at all impractical, since it prepared her well for everything in life and work (Clayton, 2000). Curious students can examine Granville's thesis abstract (Boyd, 1949), but the content on Laguerre series in the complex domain is too advanced for school classrooms. The NCTM number and operations standard specifies that students should understand complex numbers as solutions to quadratic equations with no real solutions, and Granville could be mentioned in that context.

Activities Related to her NASA Work

Evelyn Boyd Granville loved working for NASA's space programs:

> *I can say without a doubt that this was the most interesting job of my lifetime - to be a member of a group responsible for writing computer programs to track the paths of vehicles in space*. (Granville, 1989)

A slide containing pictures of Granville and this quotation is available to print and project (Greenwald, 2008).

Many related student worksheets and activities are available. In fact, NCTM and NASA partnered to produce aerospace activity books that align with the standards for Pre K-2 (Hynes & Blair, 2005), grades 3-5 (Hynes & Hicks, 2005), grades 6-8 (Hynes & Dixon, 2005), and grades 9-12 (House & Day, 2005).

Many on-line lesson plans can also be found. For example, students in grades 6-8 can learn about the time and distance required for travel in the solar system (National Council of Teachers of Mathematics, 2008) or they can become scientists and engineers as they launch spacecraft (Space Explorers, 2008). Teachers of grades 5-6 can even access lesson plans on trajectory and projectile motion designed for them by grade 9 students (Leaf, 2008).

Students interested in Granville's orbital computations can access an article detailing the contributions, procedures, and equipment of mathematicians, engineers, and programmers who worked on Project Mercury (Gass, 1999). Advanced high school students in calculus or physics can also explore a technical article related to

Project Mercury (National Aeronautics and Space Administration, 1962) that is dated from the time that Granville was working on the Mercury program.

Activity Sheet: Granville's Challenge
Granville says (Granville, 2007):

> *My advice to teachers of mathematics is to stress problem solving and stress techniques available for problem solving.*

She then illustrates her teaching philosophy by sharing her favorite challenge. The activity sheet that follows at the end of this article explores this challenge.

The first portion of the activity sheet is designed for young children and relates to the algebra standard for Pre-K-2, which specifies that students should sort, classify, and order objects by size, number, and other properties. Wang explored the challenge with his five-year old child and the questions listed under Method 1 are adapted from his reflections (Wang, 2003).

The remainder of the activity sheet is designed for students in grades 7-10. Students use a variety of methods to solve the challenge, including algebraic and geometric techniques. The problem solving standard specifies that students should apply and adapt a variety of appropriate strategies to solve problems. The extension questions in the worksheet are also designed for these types of students.

Advanced students, such as those in linear algebra, can use matrix methods to solve the challenge. The number and operations standard for grades 9-12 specifies that students should understand vectors and matrices as systems and should develop their understanding of properties and representations of multiplication of matrices, and this activity sheet could be used as a way to introduce or review matrix methods.

Activity sheet solutions can be found at http://www.mathsci.appstate.edu/centroid/.

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Picture Credits: The 2001 picture of Granville was taken at Yale University when Granville received an honorary degree (Spangenburg & Moser, 2003). The picture of Haynes is from the Catholic University of America archives. The 1997 picture of Granville was taken by Margaret Murray (Murray, 2000).

Activity Sheet: Evelyn Boyd Granville's Favorite Challenge

Evelyn Boyd Granville in 1997

Evelyn Boyd Granville was the second black woman we know of to receive her PhD in mathematics. Dr. Granville's original research related to complex numbers but she also worked on numerous space missions, including Project Mercury, the first manned space flight program: *I can say without a doubt that this was the most interesting job of my lifetime - to be a member of a group responsible for writing computer programs to track the paths of vehicles in space* (Granville, 1989). In this worksheet we will explore topics related to her favorite challenge.

My favorite challenge to teachers and children is to solve the following problem using three different methods: Rabbits and chickens have been placed in a cage. You count 48 feet and seventeen heads. How many rabbits and how many chickens are in the cage? (Granville, 2007)

Method 1

1. Sketch seventeen circles to represent the seventeen heads.
2. How many feet do chickens have?
3. How many feet do rabbits have?
4. Notice that rabbits and chickens each have at least two feet. Draw two feet attached to each head.
5. How many feet did you draw?
6. How many feet remain from the 48 total feet?
7. Do the remaining feet belong to chickens or rabbits?
8. Distribute the remaining feet on some of the heads to complete the pictures.
9. How many heads have two feet?
10. How many heads belong to the chickens?
11. How many heads belong to the rabbits?

Additional Methods Let x = the number of rabbits and y = the number of chickens

12. In terms of x and y, how many heads are there?
13. In terms of x and y, how many feet are there?
14. Solve these equations for x and y using at least two different methods.

Extensions

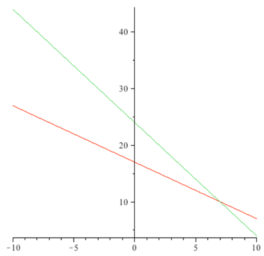
15. In real-life we know there are more feet per chicken and rabbit than heads, but can the number of heads and feet ever equal each other mathematically? If so, find a general criterion.
16. Can you find general criteria for the numbers of heads and the feet that result in an equal number of rabbits and chickens? Do the solutions always make sense in real-life?
17. Given a certain number of heads and feet, must a mathematical solution for the numbers of rabbits and chickens always exist? Explain why or find a counterexample.

Solutions for Evelyn Boyd Granville's Favorite Challenge Activity Sheet

Method 1
Chickens have 2 feet. Rabbits have 4 feet. Initially, we draw 17×2=34 feet and so 48-34=14 feet remain. These remaining feet must belong to the rabbits. Once they are added to the drawing, 10 heads have two feet and are chickens, and the remaining 7 heads with four feet are rabbits.

Additional Methods Let x = the number of rabbits and y = the number of chickens. Then we have $x + y = 17$ heads and $4x + 2y = 48$ feet. Students can solve this problem a number of ways, such as

- Substitution: Since $y = 17 - x$ then $48 = 4x + 2y = 4x + 2(17 - x) = 2x + 34$, and so $14 = 2x$. Thus $x = 7$, and substituting into the first equation yields $y = 10$.
- Graphical intersection:



- Reducing the Augmented Matrix or Invertible Matrix Methods

1 1 17 reduces to 1 0 7
4 2 28 0 1 10

or

1 1 has inverse -1 ½
4 2 2 -½

so the inverse can be applied to the column vector (17,28) to obtain the solution.

Extensions As above, let x = the number of rabbits and y = the number of chickens so that we have $4x + 2y$ feet and $x + y$ heads.

- Setting the number of heads and feet equal to each other reduces to the equation $3x = -y$, so there are mathematical solutions.
- If there are an equal number of rabbits and chickens, then $x = y$. Substituting for y in the equations yields $6x$ feet and $2x$ heads. As long as the ratio of feet to heads is 3 to 1, then there are mathematical solutions. In addition, the number of heads must be divisible by 2. Otherwise, the number of feet will be odd, and we will end up with fractions of chickens and rabbits, such as when we have 51 feet and 17 heads, which result in 17/2 rabbits and 17/2 chickens.
- Solutions must always exist mathematically. The lines have different slopes, so they will intersect. Alternatively, the coefficient matrix for the system has determinant -2 and so it is invertible.