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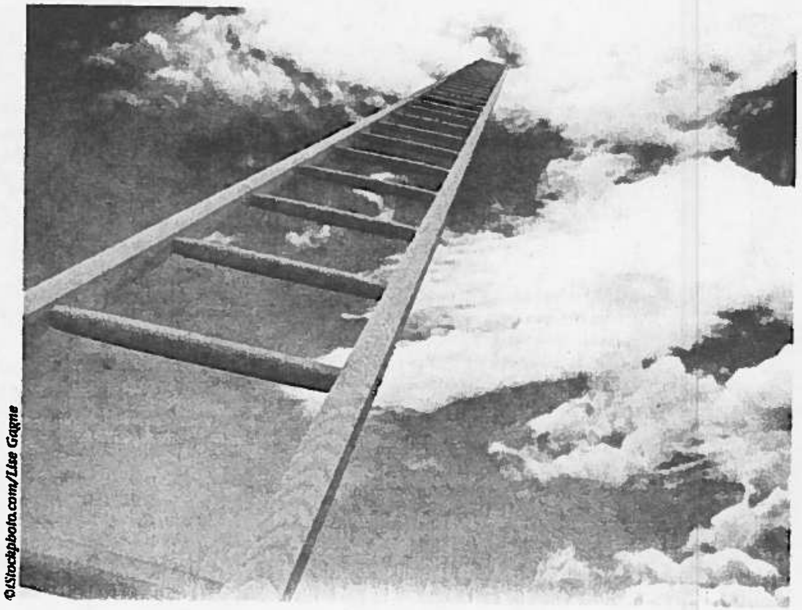

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What's Math Got to Do with It?

How Parents and Teachers Can Help Children Learn to Love Their Least Favorite Subject

Jo Boaler

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How Girls and Women Are Kept Out of Math and Science

When I started my research at Amber Hill, Caroline was fourteen years old, eager to learn, and very accomplished. When the students had entered the school some three years earlier, they had all been given a math test. Caroline had earned the highest score in her year, but three years after coming to the school she was the lowest-achieving student in her group. How could it all have gone so badly wrong? When I met Caroline, she had just been placed into the top set—a group that was taught by Tim, the friendly and well-qualified math department chair. But Tim was a traditional teacher and he, like most math teachers, demonstrated methods on the board and then expected students to work through exercises practicing the techniques. Caroline sat at a table of girls, six of them in total. All of the girls were high achievers and they all wanted to do well in math. From the beginning, Caroline looked uncomfortable in class. She was an inquisitive and thoughtful girl, and whenever Tim explained methods to the class, she, like many girls I have taught and observed over the years, had questions: Why does that method work? Where does it come from? And how does that fit with the methods we learned yesterday? Caroline asked Tim these questions from time to time, but he would generally just re-explain the method, not really appreciating why she was asking. Caroline became less and less happy with math and after a while her achievement started to decline.

In one of their lessons the students were learning about the multiplication of binomial distributions. Tim had taught students to multiply binomial expressions such as

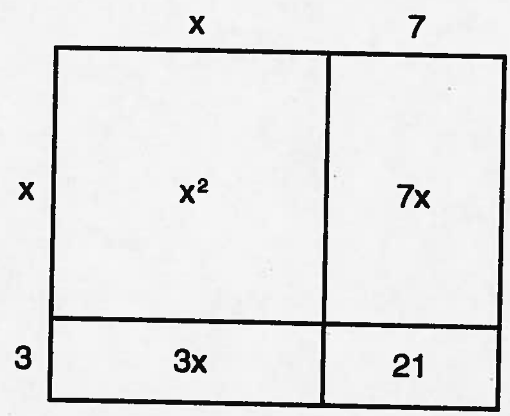
$$(x+3)(x+7)$$

by telling students that they:

1. Multiply the First terms (x times x)
2. Multiply the Outer terms (x times 7)
3. Multiply the Inner terms (3 times x) and then
4. Multiply the Last Terms (3 times 7) Then add all the terms together ($x^2 + 7x + 3x + 21 = x^2 + 10x + 21$)

Students are often taught to remember this sequence with the pneumonic FOIL (first, outer, inner, last). These are the sorts of procedures in math class that often seem meaningless to students—they are hard to remember and easy to muddle up. I approached Caroline's group one day as she was sitting with her head in her hands. I asked her if she was all right, and she looked at me with an agonized expression. "Ugh. I hate this stuff," she said. "Can you tell me why it works like this? Why does it have to be in that order, with all of that adding?" She had tried asking Tim, who had told her that that is how the formula works and you just need to remember it.

I knelt beside Caroline's desk and asked her whether I could draw a diagram for her. I explained that we could think about the multiplication visually by thinking of the two expressions as sides of a rectangle. She sat up and watched as I drew a sketch:



Soon all the girls at the table were watching. Before I had finished the drawing, Caroline said, "Oooh, I see it now," and the others made similar appreciative noises. I felt a bit bad about offering this drawing, as my role in the classroom was not to help students and certainly not to undermine Tim's teaching, but it was an opportunity that I took on that one occasion. The drawing was simple but it offered a lot—it allowed the girls to see *why* the method worked and that was important for them.

I observed Tim's class, and other classes at the school, many times over the three years. As I interviewed more and more of the boys and girls, I started to notice that the desire to know *why* was something that separated the girls from the boys. The girls were able to accept the methods that were shown to them and practice them, but they wanted to know *why* they worked, *where* they came from, and how they *connected* with other methods. Some of the boys were also curious about the ways methods were connected and how they worked, but they seemed willing to adapt to a teaching approach that did not offer them such insights. In interviews the girls would frequently say such things as "He'll write it on the board and you end up thinking, 'Well, how come this and this? How did you get that answer? Why did you do that?' "

Many of the boys, on the other hand, would tell me that they were happy as long as they were getting answers correct. The boys seemed to enjoy completing work at a fast pace and competing with other students, and they did not seem to need the same depth of understanding. John (year 10) spoke for many of the boys when he said "I dunno, the only maths lessons you like are when you've really done a lot of work and you're proud of yourself because you've done so much work, you're so much ahead of everyone else."

In a questionnaire I gave to the whole of the year cohort, I asked the students to rank five ways of working in mathematics. Ninety-one percent of girls chose "understanding" as the most important aspect of learning mathematics, compared with only 65 percent of the boys, which was a statistically significant difference.[1] The rest of the boys said that the memorization of rules was the most important. The girls and boys also acted differently in lessons. During the hundred or so lessons that I observed, I would often see boys racing through their textbook questions, trying to work as quickly as possible and complete as many questions as they could. I would, just as frequently, observe girls looking lost and confused, struggling to understand their work, or giving up all together. In lessons I would often ask students to explain to me what they were doing. The vast majority of the time, the students would tell me the chapter title and, if I asked them questions like "Yes, but what are you actually *doing*?" they would tell me the number in the exercise; neither girls nor boys would be able to tell me why they were using methods or what they meant.

On the whole the boys were unconcerned by this as long as they were getting their questions right, as Neil told me in interview: "Some of the stuff you do, it's just hard and some of it's really easy and you can remember it every time. I mean, sometimes you try and race past the hard bits and get it mostly wrong, to go onto the easy bits that you like."

The girls would get questions right, but they wanted more. As Gill explained: "It's like, you have to work it out and you get the right answers but you don't know what you did. You don't know how you got them, you know?"

At the end of the three years, the students took a national examination. In the top set (similar to honors class in the U.S.), which I had observed so closely, the girls achieved at significantly lower levels than the boys, which was a pattern that was repeated in different groups across the year cohort. Caroline, once the glittering star of the group, achieved the lowest grade of all. By the time she was finishing the course, she had decided that she was no good at math, despite the fact that she had shown a great aptitude for it some years earlier. Caroline, and many of the other girls, had underachieved because they had not been given the opportunity to ask why methods worked, where they came from, and how they were connected. Their requests were not at all unreasonable—they wanted to locate the methods they were being shown within a broader sphere of understanding. Neither the boys nor the girls particularly liked the traditional mathematics lessons at Amber Hill—math was not a popular subject at the school—but the boys worked within the procedural approach they were given whereas many of the girls resisted it. When they could not get access to the depth of understanding they wanted, the girls started to turn away from the subject. National statistics tell us that girls now do very well in mathematics, achieving at equal or higher levels than boys. This high achievement, given the inequitable approach that most girls experience, is testament to their capability and impressive motivation to do well. But the high achievement of girls often masks a worrying reality—the approaches they experience make many girls uncomfortable and their lack of opportunity to inquire deeply is the reason that so few women take mathematics to high levels.

At Phoenix Park School—where students were taught through longer, more open problems and they were encouraged to ask why, when, and how—the girls and boys achieved equally, and both groups achieved at higher levels than the students at Amber Hill on a range of assessments, including national exams.

Some years later, I was sitting in a math class myself, having decided to take some higher level classes. We had a wonderful teacher, a woman who explained why and how methods worked—almost all of the time. I remember one day sitting in class when our teacher showed the formula for standard deviation and then said, "By the way, would you like to know why it works?" Then a funny thing happened. The women in the class chorused yes and most of the men chorused no. The women joked with the men, asking, "What is wrong with you?!" One of the men responded quickly: "Why do we need to know why? It is better just to learn it and move on." It was then that I realized we were playing out the same gender roles as the students I had been observing at Amber Hill.

In one of my first research studies at Stanford, conducted in 1999, I decided to learn more about the experiences of high-attaining students in American high school classes. I chose six schools and interviewed forty-eight boys and girls about their experiences in AP calculus classes. In four of the schools the teachers used traditional approaches, giving the students formulas to memorize without discussing why or how they worked.

In the other two schools the teachers used the same textbooks, but they would always encourage discussions about the methods that students were using. I was not investigating or looking for gender differences, but I was struck again by the reflections of the girls in the traditional classes and their need to inquire deeply, as Kate at Lewis school described:

> We knew *how* to do it. But we didn't know *why* we were doing it and we didn't know how we got around to doing it. Especially with limits, we knew what the answer was, but we didn't know *why* or *how* we went around doing it. We just plugged into it. And I think that's what I really struggled with—I can get the answer, I just don't understand *why*.

Again, many of the girls told me that they needed to know *why* and *how* methods worked, and they talked about their dislike of classes in which they were just asked to memorize formulas, as Kristina and Betsy at the Angering school described:

> **K:** I'm just not interested in, just, you give me a formula, I'm supposed to memorize the answer, apply it, and that's it.
>
> **JB:** Does math have to be like that?
>
> **B:** I've just kind of learned it that way. I don't know if there's any other way.
>
> **K:** At the point I am right now, that's all I know.

Kristina went on to tell me that her need to explore and to understand phenomena was due to being a young woman:

> Math is more like concrete, it's so "It's that and that's it." Women are more, they want to explore stuff and that's life kind of, like, and I think that's why I like English

> and science. I'm more interested in like phenomena and nature and animals and I'm just not interested in just you give me a formula, I'm supposed to memorize the answer and apply it, and that's it.

It was unfortunate for Kristina that mathematics was not one of her school subjects that allowed her to "explore" or to consider phenomena, when it should have been.

David Sela, from the ministry of education in Israel, and Anat Zohar, from the Hebrew University in Jerusalem, conducted an extensive investigation of gender differences in the learning of physics. They took my notion of the quest for understanding that I had found to be prevalent among girls in math classes and considered whether it was also prevalent among girls in physics classes. They found, resoundingly, that it was. The researchers drew from a database of approximately four hundred high schools in Israel that offered advanced placement physics classes. They sampled fifty students from the schools and interviewed twenty-five girls and twenty-five boys. They found that the girls in physics classes were exhibiting the same preferences that I had found in mathematics classes, resisting the requirement to memorize without understanding, saying that it was "driving them nuts." The girls talked about wanting to know why methods worked and how they were linked. The authors concluded that "Although both girls and boys in the advanced placement physics classes share a quest for understanding, girls strive for it much more urgently than boys, and seem to suffer academically more than boys do in a classroom culture that does not value it."[2]

Neither the female math students I interviewed nor the female physics students interviewed in Israel wanted an easier science or math. They did not need or want softer versions of the subjects. In fact, the versions of mathematics and science they wanted required considerable depth of thought. In both cases the girls wanted opportunities to inquire deeply, and they were averse to versions of the subjects that emphasized rote learning. This was true of boys and girls, but when girls were denied access to a deep, connected understanding, they turned away from the subject.

The differences that have been found between girls and boys in mathematics and physics classes do not suggest that all girls behave in one way and all boys in another. Indeed, Zohar and Sela found that one third of the boys they interviewed also expressed strong preferences for a deep, connected understanding. But they, like I, found that girls consistently expressed such preferences in higher numbers and with more intensity. Such gender differences are interesting and, until recently, have been somewhat puzzling.

The idea that girls and women value a different type of knowing was famously proposed by Carol Gilligan, an internationally acclaimed psychologist and author. In Gilligan's book *In a Different Voice,* she claimed that women are likely to be "connected thinkers," preferring to use intuition, creativity, and personal experience when making moral judgments. Men, she proposed, are more likely to be "separate" thinkers, preferring to use logic, rigor, absolute truth, and rationality when making moral decisions.[3] Gilligan's work met a lot of resistance, but it also received support from women who identified with the thinking styles she described. Some years later a group of researchers developed Gilligan's distinctions further, claiming that men and women differ in their ways of knowing, more generally. Psychologists Mary Belenky, Blythe Clinchy, Nancy Goldberger, and Jill Tarule,[4] proposed stages of knowing, and again claimed that men tended to be separate thinkers and women connected thinkers. The authors did not have a lot of data to support their claims that women and men think differently, and they received considerable opposition, which is understandable given that they were suggesting fundamental distinctions in the way women and men come to *think* and *know*. When I reported my own findings, that girls were particularly disadvantaged by traditional instruction that did not give them access to knowing how and why, I also received resistance. Indeed, some of my colleagues challenged me, saying that it was not possible that girls would have different preferences from boys in such a cognitive domain. They asked me for the reason for such differences and I admitted that it was not clear. Despite vastly different socialization processes that girls and boys are subjected to from an early age, there seemed to be no obvious reason for their different preferences in math and science knowing. That is, until now.

Emerging Research on the Brain

One of the most interesting developments of the twenty-first century has been a new form of technology that is allowing neuroscientists to map the workings of the human brain. Louann Brizendine, a neuropsychiatrist and author of the book *The Female Brain,* explains that brain-imaging technology has allowed scientists to document "an astonishing array of structural, chemical, genetic, hormonal and functional brain differences between men and women."[5] Researchers have now found that women and men use different brain areas to solve problems, even when they score exactly the same on tests. For example, researchers found that when participants were asked to mentally rotate three-dimensional shapes, they were equally good at it, but women and men used completely different brain circuits.[6] Here are some of the most interesting findings from brain-imaging research:

1. While scientists have known for hundreds of years that men's brains are bigger than women's, even when controlling for men's greater average size, they now know

that women and men have exactly the same number of brain cells and so have equal intelligence. In men's brains, the cells are packed less densely.

2. A huge testosterone surge beginning in the eighth week of pregnancy kills cells in the communication centers of male brains and grows more cells in the sex and aggression centers. In the brain centers for language and hearing, for example, women have 11 percent more neurons. Strikingly, Brizendine reports that men use about seven thousand words per day and women about twenty thousand.[7] The fact that autism, a communication disorder, affects eight times as many boys as girls is thought to be due to the fact that men's brains offer less support for communication.

3. From the first days after birth, girl babies are more attuned to faces and human interactions. In a study conducted by graduate student Jennifer Connellan and her Cambridge University professor Simon Baron-Cohen that compared newborn babies on the day they were born, babies were given a choice between looking at a simple dangling mobile or a young woman's face. Videotapes of 102 babies' eye motions were analyzed by researchers who did not know the sex of the babies. Boy babies were almost twice as likely to look at the mobile than girl babies, who preferred to look at the woman's face. The researchers concluded "beyond reasonable doubt" that sex differences in social interest must, in part, be biological.[8]

4. Brain function is more compartmentalized in men than in women. In men, the left side of the brain is specialized for language function, but women's brains are

more symmetrical. Research on stroke victims shows that when men have a stroke involving the brain's left hemisphere they drop their verbal IQ by about 20 percent, whereas those who have a stroke involving the right hemisphere do not drop any verbal IQ points. Women who have a stroke involving the left hemisphere drop their verbal IQ by about 9 percent, those who have a stroke involving the right hemisphere drop their verbal IQ by about 11 percent. Scientists conclude from this that women use both sides of their brain for language and men do not.[9]

5. In a study at Stanford University, Brizendine reports, researchers studied the brains of volunteers who were viewing emotional images. The brain scans showed that nine different brain areas lit up in women, but only two in men.[10]

6. Brain-imaging studies have found that for many tasks, including mathematical work, women use the more advanced area of the brain (the cerebral cortex), whereas men use the more "primitive" areas of the brain such as the globus pallidus, the amygdala, or the hippocampus.[11]

These and other striking findings lead Brizendine to conclude that the girl brain is "a machine that is built for connection."[12] Leonard Sax, a physician and author of the book *Why Gender Matters: What Parents and Teachers Need to Know about the Emerging Science of Sex Differences,* also reviews the research on brain differences and draws similar conclusions to Brizendine. Sax argues that girls and boys hear differently (and he presents evidence that girls hear better than boys), play differently, and learn differently. Part of the evidence that Sax gives for his claim that girls and boys learn differently is that brain-imaging studies have found that men and women use different areas of the brain when they complete tasks. Sax concludes that the male and female brains are equally powerful but organized differently and suited to different tasks.

Both of the authors conclude that women and girls are naturally inclined toward communication and connection making, and they both draw conclusions about the ways girls and boys should learn math and science, but only one author's conclusions are supported by educational research. Louann Brizendine makes a point that is supported by findings on successful and less successful teaching environments. She says, quite rightly, that girls often reject mathematics because they want to be learning subjects that involve more communication and more connections with people. At a time when young people are choosing career paths, the male brain, Brizendine explains, is flooded with testosterone and boys become content with more solitary pursuits. At the same time, young women often look to work with people and to learn collaboratively. These female choices become incompatible with the way mathematics is generally taught, *but not the way it should be taught*. When I interviewed students in AP calculus classes, the girls who were taught in classes that encouraged the discussion of concepts saw mathematics as compatible with their preferences for communication, understanding, and depth. Veena, who planned to major in mathematics, commented:

> Sometimes you sit there and go, "it's fun!" I'm a very verbal person and I'll just ask a question and, even if I sound like a total idiot and it's a stupid question, I'm just not seeing it, but usually for me it clicks pretty easily and then I can go on and work on it. . . . There's this certain point when it just connects and you see the connection and you get it.

Classes in which students discuss concepts, giving them access to a deep and connected understanding of math, are good for girls and for boys. Boys may be willing to work in isolation on abstract rules, but such approaches do not give many students, girls or boys, access to the understanding they need. In addition, high-level work in mathematics, science, and engineering is not about isolated, abstract rule following, but about collaboration and connection making.

Sax draws different conclusions about the implications of differences in brain functioning for mathematics learning, but they are not supported by educational research. He notes that brain imaging has shown that when girls work on math problems, they are using the cerebral cortex, which is the part of the brain that mediates language and higher cognitive functions, whereas boys use the hippocampus, "a phylogenetically primitive area of the brain that is pre-wired for spatial navigation."[13] Sax points out, quite correctly, that girls need math to be tied into higher cognitive functions, but his suggestion is that boys are taught using raw numbers, isolated from contexts, whereas girls are taught the same math using real-world contexts. He gives the teaching of Fibonacci numbers as an example with the boys being given the fascinating sequence to explore and girls being asked to bring in objects from the world such as artichokes, sunflowers, and pinecones. Sax proposes that girls would then ask questions such as "Why do numbers in the Fibonacci sequence keep showing up when you count the petals on a delphinium?" and "How can abstract number theory explain these similarities?" He is right about the *why* questions girls may ask but wrong in suggesting that girls need real-world examples. The reality is that girls would enjoy exploring sequences of numbers just as much as the boys if they were inquiring deeply about them, and boys would enjoy considering real-world phenomena. A good approach to the teaching of mathematics would involve both aspects of mathematical work—abstract and applied. Sax suggests putting boys into one class and giving them a disconnected (and distorted) approach and girls into another to get a connected but equally distorted version of mathematics. Even if girls did perform better when concepts were introduced via real-world phenomena, the math curriculum would be pretty sparse if it only involved concepts that could be illustrated in such ways. The fact is that girls enjoy playing with numbers and number sequences and they do not need them to be embedded in the real world if the concepts are connected to other mathematical concepts, and if there is discussion of *how* and *why* they work.

In addition, brain differences are not so compelling that they justify teaching girls and boys separately. We know that brain differences only explain gender tendencies and that there are plenty of boys who value and need connections and communication and who choose other subjects because mathematics does not offer these, just as there are girls who can happily work in isolation without mathematical connections. I would pity those girls and boys who did not conform to the ways of thinking and working that were typical for their gender but who were forced to be taught via a distorted version of mathematics that was entirely abstract or entirely based in the real world. If mathematics teaching included opportunities for discussion of concepts, for depth of understanding, and for connecting between mathematical concepts, then it would be more equitable and good for both sexes, and it would give a more accurate depiction of mathematics as it is practiced in high-level courses and professions.

Brain research is still in its infancy but the question of *why* women and girls want to inquire deeply is not as important as the question of how we provide environments in which they can.

Where Are We Now?

Given the ways in which mathematics is commonly taught and the preferences of many girls for deep understanding and inquiry, it is perhaps surprising that girls do as well as they do in mathematics—and they do perform very well. In 2002 and 2004, for example, women made up 47 percent of mathematics majors and 48 percent of the AP calculus cohort, respectively. These statistics may be surprising as there is widespread public belief, fueled by sensationalist media reports, that boys are way ahead of girls in mathematics, which is far from the truth. Psychologists Janet Hyde, Elizabeth Fennema, and Susan Lamon produced a meta-analysis[14] of studies that have investigated gender differences in achievement, combining over one hundred studies involving three million subjects. Even in 1990, with such a vast database, they found very small differences between girls and boys, with a huge amount of overlap.[15] Hyde and her colleagues argued that gender differences were too small to be of any importance, and that they have been overplayed in the media, which has helped to create stereotypes that are damaging.

In most examinations in the U.S. there are also no recorded gender differences in mathematics. The small performance differences that exist take place only on the SAT[16] and the Advanced Placement (AP) examinations (in 2002 the average score of girls was 3.3 compared to boys' 3.5). In England, a country with a similar education system, girls used to achieve at lower levels than boys on examinations, but now they achieve at higher levels in all subjects. In fact, the results for girls and boys in England have shifted in interesting ways over time. In England, at age sixteen, almost all students take the General Certificate of Secondary Education (GCSE) examination in mathematics. As mathematics is compulsory until age sixteen, equal numbers of boys and girls take this examination. In the

1970s, boys passed the mathematics GCSE examination[17] in higher numbers and attained more of the highest grades; in the 1990s, girls and boys passed the exam in equal numbers but boys achieved more of the highest grades. By the 2000s, girls were passing the exam at higher rates than boys and attaining more of the highest grades.[18] In England, girls now outperform boys in all subjects, including mathematics and physics, on the GCSE and beyond, and they now attain more of the highest grades in the most demanding high-level examinations.

Girls are doing very well now in the U.S., England, and many other countries, but their strong performance hides a worrying fact—most mathematics classrooms are not equitable environments and girls often do well despite inequitable teaching. This is the reason that girls often opt out of mathematics even when they are achieving at high levels and even though a mathematical or scientific career could be very good for them. In high-level courses and mathematical jobs, the statistics are quite alarming. In 2000, 27 percent of mathematics PhDs went to women. In 2003, women made up only 8 percent of the mathematics faculty, 7 percent of the physics faculty, and 7 percent of the engineering faculty in the top science and engineering departments in America. The low numbers of women working as researchers and scientists across Europe is one of the priority areas for the European Union. Fifty-two percent of higher education graduates across Europe are women, but only 25 percent of these women take science, engineering, or technology subjects. Girls do well in math and science because they are capable and conscientious, but many do so through endurance, and math classroom environments are far from being equitable. Indeed, it is the impoverished version of mathematics that is offered to students that turns many people, female and male, away from the subject.

Other Barriers

Of course, the lack of opportunity to inquire deeply is not the only barrier to girls and women in mathematics and science. Mathematics classrooms in schools are considerably less gender stereotyped than they were twenty years ago, when sexist images prevailed in textbooks and mathematics teachers were found to give boys more attention, reinforcement, and positive feedback,[19] but still girls in some classrooms experience stereotyped attitudes and behaviors, contributing to their low interest and participation in math. Some school mathematics and science classrooms are also highly competitive, which deters many young women.

In university math departments the situation is worse. Abbe Herzig, a professor at the State University of Albany, New York, has produced evidence of the ways in which the climates of university mathematics departments can be icy cold toward women and minority students.[20] Herzig notes that women face many issues including sexism, stereotyped ideas about women's capabilities, feelings of isolation, and lack of role models,[21] especially at the graduate level. By and large, math departments in the U.S. remain a male preserve where the underrepresentation of women among students is eclipsed only by the underrepresentation of women among the faculty. At Stanford University there used to be no women's bathrooms in the mathematics department. When I last visited the department in 2005, they had still not built women's bathrooms; they had just added WO to the MEN sign on some doors and put pots of flowers in the urinals, which still remained. What sort of message does that send to the women taking courses in mathematics? There could not be a clearer statement about the absence of women in the history of the department or the lack of concern for their sense of inclusion now.

The teaching in mathematics departments can also be highly rule-based, which again denies girls the opportunity to ask why and how, as Julie, one of the young women who had given up on her mathematics degree at Cambridge University, explained to me:

> I think it was my fault because I did want to understand every single step and I kind of wouldn't think about the final step if I hadn't understood an in-between step. . . . I couldn't really see *why* they, *how* they got to it. Sometimes you want to know; I actually wanted to know.

For Julie, who had won awards for her mathematics achievement prior to attending Cambridge, her desire to understand how and why methods worked stopped her from going forward with the subject.

Societal Stereotypes

In addition to the problems in university mathematics departments and schools, young women and men suffer from the stereotypes that are perpetuated in society, particularly by the media. Ideas such as girls being too nurturing and caring to work in the hard sciences are based upon incorrect ideas about women and about the ways mathematics and sciences work. Girls and women do not need a softer version of mathematics. Indeed, the sorts of inquiries women need could be said to epitomize true mathematical work, with its need for proof and rigorous analysis of ideas.

When girls went ahead of boys in mathematics and science (and all other subjects) in England, alarm bells rang everywhere. Suddenly there was government money to look into gender relations in math and science, something that had never happened when girls were underachieving. It was interesting that, whereas people had always decided that the underachievement of girls in math and science was due to their intellect, when it was boys who were underachieving, people looked to external reasons—with suggestions that the books must be biased, the teaching approaches favored girls, or that teachers must be encouraging girls more. Nobody suggested that boys did not have the brains for math or science. Michele Cohen, a historian, gives an interesting perspective on the tendency of people to locate girls' underachievement *within* girls. She points out that this has been done throughout history and that in the seventeenth century scholars went to enormous lengths to explain away the achievement of girls and the working classes, as it was boys, specifically upper-class boys, who were believed to possess true intellect. People at that time explained that the superior verbal competence noted among girls was a sign of weakness and that the English gentleman's reticent tongue and inarticulateness was evidence of the depth and strength of his mind. Conversely, women's conversational skills became evidence of the shallowness and weakness of their mind.[22] In 1897, the Reverend John Bennett, from the Church of England, argued that boys appeared slow and dull because they were thoughtful and deep and because "gold sparkles less than tinsel."[23]

The tendency to locate sources of underachievement within girls and to construct ideas about female inadequacy is also characteristic of much of the psychological research on gender. In my interviews with high school students, I frequently encounter stereotypes about the potential of girls and boys. But it is particularly disturbing when I find that ideas about girls being mathematically inferior have come from the reporting of research. In a recent interview with a group of high school students in California, I asked Kristina and Betsy about gender differences:

> **JB**: Do you think math is different for boys and girls or the same?

K: Well, it's proved that boys are better in math than girls, but in this class, I don't know.

JB: Mmm, where do you hear that boys are better than girls?

K: That's everywhere—that guys are better in math and girls are like better in English.

JB: Really?

B: Yeah. I watched it on *20/20* [a television current affairs program] saying girls are no good, and I thought, "Well, if we're not good at it, then why are you making me learn it?"

The girls refer to a television program that presented the results of research on the differences between the mathematical performance of girls and boys. The problem with some research on equity is not that researchers noted that girls were achieving less than boys, or that girls displayed less confidence in math classrooms, but that such findings were often presented as being due to the nature of girls rather than any external sources. This led educators to propose interventions that were well intentioned but that aimed to change girls. The 1980s spawned numerous programs that were intended to make girls more confident and challenging.[24] The idea behind such programs is often good, but they also lay the responsibility for change at the feet of the girls rather than mathematics teaching environments or the broader social system. On July 5, 1989, *The New York Times* ran the headline "Numbers Don't Lie: Men Do Better than Women" with an article discussing gender differences in SAT scores. But this article, like many others, used performance differences to suggest that women were mathematically inferior, rather than questioning the teaching and learning environments—as well as the biases they themselves were helping to create—that caused the underachievement of women. Now that women are ahead in most areas, it is interesting to note the absence of any analogous headlines proclaiming women's innate superiority.

It was once suggested that girls are made of "sugar and spice and all things nice"—a harmless nursery rhyme perhaps, but the idea that girls are sugary sweet and lack the intellectual rigor for mathematics and science is still around. It is time that such ideas are buried and that girls are encouraged to go into math and science, for their sake as well as the sake of the disciplines themselves. Mathematics is and has always been about deep inquiry, connection making, and rigorous thought. Girls are ideally suited to the study of high-level mathematics—and the only reason that they drop math in high numbers is because the subject is misrepresented and taught badly in too many classrooms in America.