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ABSTRACT

This Teacher Education and Mathematics (TEAM) module is designed to increase awareness of the fact that, historically, women have contributed to mathematical knowledge and mathematics education, that they continue to do so at the present time, and that these women may serve as important role models. It contains an instructor's text and student materials. The instructor's text provides (1) specific directions for the instructor to follow in guiding lessons and (2) commentary designed to help in building positive mathematics attitudes. The directions tell how to proceed step-by-step, while the commentary articulates a philosophy and provides explanations, attitudinal interventions, and instructional alternatives. This is accomplished with a special "facing pages" format. The right-hand page provides teaching directives, while the left-hand page, "commentary and notes" (or just "notes" when there is no relevant commentary) offers alternative teaching modes and psychological strategical approaches, and space for the instructor's own comments. Also included in the instructor's text are the script for the companion audiotape titled "Interviews with the Past," and a source list of books and articles on women mathematicians. Student materials include a pretest and "Famous Women Mathematicians," brief biographies of 13 female mathematicians. (JN)

Women As Mathematicians

A Course to Reduce Math Anxiety and Sex-Role Stereotyping in Elementary Education

TEAM

TEACHER EDUCATION AND MATHEMATICS

Queens College of the City University of New York
Women's Educational Equity Act Program/U.S. Department of Education

TEACHER EDUCATION AND MATHEMATICS

A Course to Reduce Math Anxiety and Sex-Role Stereotyping in Elementary Education

WOMEN AS MATHEMATICIANS

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Women's Educational Equity Act Program
U.S. Department of Education

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WOMEN AS MATHEMATICIANS

I

INSTRUCTOR'S TEXT

INTRODUCTION

The Women As Mathematicians module was prepared for use in a course or workshop series on attitudes toward mathematics. It contains an Instructor's Text and Student Materials. Both module parts can be kept in a loose-leaf notebook.

The Instructor's Text provides (1) specific directions for the instructor to follow in guiding lessons and (2) commentary designed to help in building positive math attitudes. The directions tell the instructor how to proceed step by step, while the commentary articulates a philosophy and provides explanations, attitudinal interventions, and instructional alternatives. This is accomplished with a special "facing pages" format. The right-hand page provides teaching directives, while the left-hand page, "Commentary and Notes," (or just "Notes" when there is no relevant commentary) offers alternative teaching modes and psychological and strategical approaches, and space for the instructor's own comments. Also included in the Instructor's Text are the script for the companion audiotape, Interviews with the Past, and a source list of books and articles on women as mathematicians.

Student Materials includes a pretest and "Famous Women Mathematicians," brief biographies of 13 women mathematicians.

NOTES

OVERVIEW

Women who have contributed to mathematical knowledge have been unheralded and unknown to the general public. It is unlikely that your students will be able to identify noteworthy women mathematicians. This may be attributable in part to the sharply limited number of women who have studied mathematics in the past. But it is also attributable to the lack of recognition of these women in educational materials.

The goal of this module is to increase the learner's awareness of the fact that, historically, women have contributed to mathematical knowledge and mathematics education and that they continue to do so at the present time. These women may serve as important role models.

COMMENTARY AND NOTES

Anticipate that there will be some laughter, even mild discomfort, if students feel that they should know about women mathematicians. Expect that they will not be able to answer the pretest.

Collect the pretests only if you make it clear that they will not be used in grading students' achievement.

BEGINNING THE PROGRAM

You might begin by raising some questions with your students, for example: Do you think that women have made any important contributions to mathematics? Have you ever heard of a famous woman mathematician? Have there been any outstanding women mathematicians?

Alternatively, you might begin by telling your students that you have an unusual short quiz for them to take. Distribute the pretest (see Student Materials, page II-3) and ask the students to respond to it. After a brief time, ask students if they were able to identify the women mathematicians. When it is clear that, as a group, they could not, ask, "Why do you think we had such a hard time in identifying the women mathematicians?" Lead a brief discussion that brings out the point that women have been omitted from the descriptions of mathematics discoveries and developments, and that women may not have been given due recognition for their contributions. Tell students that until recently, little information on women's achievements in mathematics has been compiled or accessible.

COMMENTARY AND NOTES

The discussion should focus on those aspects of the subject's background--family, personality, and so on--that may have contributed most toward her development as a mathematician.

ACTIVITIES

The companion audiotape, Interviews with the Past (17 minutes), presents an imaginary interview with two outstanding women mathematicians, Sophie Germain and Sonya Kovalevsky. These two people's lives were exceptionally interesting and dramatic. In introducing the audiotape, mention that these two women, who lived in the 18th and 19th centuries, were known among their peers in scientific and intellectual circles in Europe. (See the script for the audiotape, included in this section of the module, pages I-10 through I-17.)

Distribute "Famous Women Mathematicians" (see Student Materials, page II-4). These brief descriptions of 13 women mathematicians were prepared to stimulate students' curiosity as well as to provide information. On the basis of this introductory information, have students select one or two women to read about in greater depth (see the source list included in this section of the module, page I-18).

When students have read the available information, lead a discussion that considers:

1. Background features that might have stimulated mathematical interests
2. Personality and character attributes
3. Family responses to intellectual interests
4. Socioeconomic variables (e.g., financial support for intellectual pursuits, availability of educational opportunity

You may want to develop a group project in which the students write biographical sketches of the women they have read about. The sketches should focus on those aspects of each subject's background--family, personality, and so on--that may have contributed most toward her development as a mathematician.

The discussion based on the students' readings or the biographical sketches students have prepared can also be related to the classroom activities of teachers. What activities might teachers devise to assist pupils in identifying mathematical interests while they are in elementary school? Students can brainstorm ideas for classroom methods and activities--both in teaching mathematics and in teaching other subjects.

INTERVIEWS WITH THE PAST

Audiotape Script*

Characters

Interviewer

Sophie Germain, French mathematician

Sonya Kovalevsky, Russian mathematician

. . . . . .

ANNOUNCER: This tape is one of a series developed as part of the Teacher Education and Mathematics project at Queens College of the City University of New York. These tapes are designed for use in classes or as part of discussion groups.

This tape, Interviews with the Past, provides the opportunity to hear about two famous women who have contributed significantly to the field of mathematics. Let's go back in time and hear these two women being interviewed.

. . . . . .

INTERVIEWER: Good evening, and welcome to Interviews with the Past. We are privileged to have in our studio tonight two women who lived in different centuries and different countries, but who both achieved fame in the same field--mathematics.

I will be talking first with Sophie Germain, who was born in France in 1776.

Madame Germain, even today, mathematics is not a field with many women in it. In the 18th century it was even more unusual for a woman to be a mathematician. How did you first become interested in mathematics?

SOPHIE GERMAIN: I had only just turned 13 when the Bastille was stormed and the revolution began. Of course, it was a terrible, chaotic period. None of the old rules applied. There

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*Script by Sheila Crowell and Ellen Kolba.

was violence everywhere. My family was well-to-do, but not aristocratic--so we were in no danger. But my parents were in a position to protect me. Unfortunately, this meant that I could go nowhere. All my waking hours were spent indoors, and the only entertainment I had was reading.

One day, as I was working my way through my father's library, I chanced to read the story of Archimedes' death. Archimedes, you know, also lived in chaotic times. The Romans had invaded his city. But he was so absorbed in a geometry problem drawn in the sand that he failed to notice the approach of a Roman soldier and was killed.

You can imagine how that story struck me! Something that could engage one's attention to that extent was something I wanted to study! Of course, there were a few drawbacks.

INTERVIEWER: Your parents, I suppose, were opposed to your studying mathematics?

SOPHIE GERMAIN: (with a laugh) Yes, indeed. They considered it quite dangerous. They were afraid that I might injure myself in some way--overtax my brain, I suppose. And they did everything in their power to discourage me.

INTERVIEWER: Their attitude was quite common in those days.

SOPHIE GERMAIN: Yes, it was. But I disobeyed them and continued studying--often late into the night. They tried to make it impossible for me to work. They would not permit me to have a fire in my room. They took away my candles and my clothes. I suppose they thought I had no choice but to get into bed and stay there.

INTERVIEWER: And did you?

SOPHIE GERMAIN: (amused, as she remembers) Oh, briefly. I played the good girl and climbed meekly into bed, but once my parents were asleep, out I climbed again. I wrapped myself in my quilt and lit a candle from the supply I had--prudently--hidden ahead of time.

INTERVIEWER: And did your parents ever catch on?

SOPHIE GERMAIN: Oh, yes. One night I fell asleep over my books and my parents discovered me there in the morning. It was so cold that the ink had frozen in my inkhorn! Perhaps

that was what convinced them that opposition would be useless. At any rate, they allowed me to continue studying on my own.

INTERVIEWER: Did you always work on your own, or did you eventually acquire a tutor?

SOPHIE GERMAIN: I never had a tutor, nor was I allowed to attend classes when the Ecole Polytechnique opened in 1794. Women simply weren't accepted as students. But again, I had my own ways of getting around opposition. I managed, through friends, to get the lecture notes for all the courses I was interested in. And at the end of the term, when all the other students submitted papers, so did I--anonymously, of course. Or, rather, I signed my paper Monsieur LeBlanc, borrowing the name of another student at the Ecole Polytechnique.

Lagrange, the professor, was quite impressed with my work. He wanted to congratulate me in person. Anxiously my friends had to tell him that I was not a "monsieur" but a "mademoiselle." Amazingly, he took this news in his stride and insisted on meeting me.

INTERVIEWER: Lagrange was an important influence in your life. Isn't it true that he guided your career from this point on?

SOPHIE GERMAIN: (gently correcting the interviewer) Lagrange's acceptance of me was a true turning point. It gave me the courage to continue my work. Despite the intensity with which I had studied, I did have occasional doubts. (pause) Uniqueness is not always a privileged position. (pause) But Lagrange gave me a place in the scientific and mathematical community. He introduced me to people who were exploring the same sorts of problems that interested me. I was able to correspond with them, to tell them about my work, and to learn from them. (pause; then, thinking aloud) I don't know if you can imagine what a relief--and what a pleasure--it was finally to be able to talk to other people about what I was doing, after all those years of silent (pause) solitary (pause) study.

INTERVIEWER: But you never really lost your uneasiness at being a woman in a man's world, did you?

SOPHIE GERMAIN: (laughing) I suppose you are referring to my correspondence with Gauss. Yes, even though others knew who I was, when I first wrote to Gauss about his work on number theory, I became Monsieur LeBlanc again. Perhaps

it was because I initiated the correspondence with Gauss on my own--we were not introduced by Lagrange. Perhaps it was because I was rather in awe of him. At any rate, it was several years before he found me out.

INTERVIEWER: But Gauss, too, accepted you when he discovered you were a woman?

SOPHIE GERMAIN: Yes--he was even rather flattering. And, more important, he continued to write to me. Much of my work in number theory grew out of this correspondence, you know.

INTERVIEWER: Your contributions to number theory weren't the whole of your work, were they?

SOPHIE GERMAIN: No, I turned from number theory to the study of elastic surfaces, (her voice rises with excitement--this is obviously something she loves) a fascinating problem, and one that most mathematicians were reluctant to deal with at the time.

INTERVIEWER: And it was in this field that you won recognition in the scientific world, wasn't it?

SOPHIE GERMAIN: Yes, in 1816--after three tries--I won the grand prize in a competition sponsored by the French Academy. In my paper I developed a theory that would explain the patterns of vibration of elastic plates. Other papers followed--not published anonymously--and I think I was recognized as a true force in the field of mathematics. But there was one honor that was always denied me, and it still rankles today, so many years later.

INTERVIEWER: What was that?

SOPHIE GERMAIN: I was not admitted to the French Academy. But I understand that I'm in good company. Marie Curie was never admitted to the Academy, either.

INTERVIEWER: Thank you, Madame Germain. Even though the 18th century did not welcome women as mathematicians, you succeeded in making mathematics your life.

. . . . . .

ANNOUNCER: Our next guest, Sonya Kovalevsky, was born in Russia about 70 years after Madame Germain.

Madame Kovalevskaya, you've heard how Madame Germain struggled to get an education. Weren't you encouraged to study by someone in your family?

SONYA KOVALEVSKY: You might say that my Uncle Peter inspired me.

INTERVIEWER: In your book Recollections of Childhood, you describe the long discussions you and your uncle Peter had about mathematics and the sciences.

SONYA KOVALEVSKY: Yes, even though he wasn't a trained mathematician, he loved the subject. And I could sense his awe and his enthusiasm. (pause, remembering) He would toss into a conversation mathematical phrases that I could not understand, but he said them in such a way that I was drawn to their very mysteriousness. He made it seem a poetry of the mind.

INTERVIEWER: And wasn't there something else that caught your attention and focused it on mathematics?

SONYA KOVALEVSKY: (politely, questioningly) Yes?

INTERVIEWER: (jogging her memory) When you moved to the new country house?

SONYA KOVALEVSKY: (laughing delightedly) Oh, you mean the wallpaper?

INTERVIEWER: Tell us about it.

SONYA KOVALEVSKY: (with a rush of memory, as if she is reliving the moment) They had run out of paper to cover the walls of my room, and so they used some old printed lectures on the calculus that my father had bought many years before. These sheets, spotted over with strange, incomprehensible formulas, soon caught my eye. I passed whole hours of my childhood before that mysterious wall, trying to decipher even a single phrase, trying to discover what order the paper should be in. All I succeeded in doing was fixing in my mind the pattern of the formulas, not their meaning. But even that seemed wonderful to me. (drifting off, reminiscing again to herself)

INTERVIEWER: When did you discover their meaning?

SONYA KOVALEVSKY: When I was 15, my father allowed me to be tutored in mathematics. (chuckling) I will never forget how astonished my tutor was when I grasped the concepts so quickly. He said that it was almost as if I had seen them before!

INTERVIEWER: Your parents encouraged you in your studies?

SONYA KOVALEVSKY: Only to a point, only to a point. And of course, where could I go after the tutoring? Russian universities were closed to women. And so I languished for a while.

INTERVIEWER: When did things change?

SONYA KOVALEVSKY: After I became interested in literature.

INTERVIEWER: How did literature help you pursue mathematics?

SONYA KOVALEVSKY: My sister and I belonged to a literature group in Moscow. There we met Dostoevsky.

INTERVIEWER: (surprised) And he helped?

SONYA KOVALEVSKY: Yes, he introduced us to his circle of friends--a group of European intellectuals living in Moscow. And through them we heard of means of escape.

INTERVIEWER: What was that?

SONYA KOVALEVSKY: To marry.

INTERVIEWER: (again surprised) How could marriage be a means of escape?

SONYA KOVALEVSKY: One had to choose wisely, of course, but marriages of intellectual convenience were not uncommon in that elite circle. One would marry a studious young man. Then the husband and wife could travel to a foreign university, bringing one's sister along, and all would be free to study.

INTERVIEWER: And you were the one elected?

SONYA KOVALEVSKY: Yes, Kovalevsky and I were married in the fall of 1868, and the following spring we all went to Heidelberg, in Germany, where I was given special permission to attend lectures. My husband soon left to study elsewhere, but since we were friends, not lovers, at that time, we were both satisfied.

INTERVIEWER: How long did you stay there?

SONYA KOVALEVSKY: About two years. In 1870 I went to Berlin to study under Weierstrass--a great mind and a very great man. When they would not let me attend his lectures, I went to him directly. He sent me away with a set of difficult problems to solve--to test me, of course--no doubt thinking that he had seen the last of me. When I returned the answers in one week, he was so astonished,

not only at my accuracy but at my originality, that he became my champion.

INTERVIEWER: In what way?

SONYA KOVALEVSKY: He fought the administration to try to get me admitted. When that failed, he took me on as a private student. After four years I received a doctorate for the work I had done. Oh, not from Berlin, of course, but from Göttingen, where they were not so blind to see the capabilities of a mere woman.

INTERVIEWER: So in 1874 you became Dr. Kovalevsky.

SONYA KOVALEVSKY: Yes, and we returned to Russia, where Vladimir and I finally became true husband and wife. When our child was born--our darling girl, Foufie--I became immersed in motherhood and wrote my first novel.

INTERVIEWER: Why did you abandon mathematics?

SONYA KOVALEVSKY: (stiffly) I did not abandon mathematics. I was abandoned by it. In Russia, they would only let me teach arithmetic--in a girls' school--at the elementary level. And so I was drawn to literature again, until--

INTERVIEWER: Until what?

SONYA KOVALEVSKY: Until my husband's business ventures began to fail and we needed more money. I went to Berlin again to work with Weierstrass. He tried to get me a teaching position in Germany, but it was impossible. Then (voice faltering) Vladimir failed completely. All his schemes brought us to bankruptcy, and he (pause) in despair (pause) committed suicide.

INTERVIEWER: (gently) And so you were penniless and alone and had a child to support.

SONYA KOVALEVSKY: Suddenly, when things seemed darkest, the light shone again. One of Weierstrass's former students invited me to teach at Stockholm. While I was there, I received my greatest award, the Prix Bordin of the French Academy of Science. I won it in 1888 for a paper on the rotation of a solid body about a fixed point. Fortunately, all papers were submitted anonymously. If they had known mine was written by a woman, they would probably have discarded it without reading it. Because of this prize, I was finally given tenure and professorship at Stockholm University.

INTERVIEWER: You had, it seems, everything a woman of your time could have had.

SONYA KOVALEVSKY: (a tinge of bitterness in her voice) But what a lot I gave up. I was separated from my sister, my country, and even, at times, my child. And the man I had come to love could not accept the importance of my work and so we parted. (softly) I was never sure that I was doing the right thing, only that I had to do it.

INTERVIEWER: You put your feelings into the novels you wrote.

SONYA KOVALEVSKY: Yes, they were my outlet. I often wonder which interest of mine would have claimed me if I had lived longer. I died at 41, never knowing which was more important to me--the poetry of the mind or the poetry of the soul.

INTERVIEWER: Madame Kovalevsky, you may wonder, but the world does not. Your novels are interesting and well written, but your mathematical work on differential equations is the work of genius and has never been superseded. You were a true poet in both fields. May that poetry inspire others!

. . . . . .

ANNOUNCER: You have been listening to Interviews with the Past and have heard from Sophie Germain and Sonya Kovalevsky, two distinguished women mathematicians in history.

This tape was produced by the Teacher Education and Mathematics project, Queens College of the City University of New York, under a grant from the U.S. Department of Health, Education and Welfare, Office of Education, under the auspices of the Women's Educational Equity Act. Opinions expressed herein do not necessarily reflect the position or policy of the Office of Education or the Department and no official endorsement should be inferred.

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WOMEN AS MATHEMATICIANS

II

STUDENT MATERIALS

PRETEST

Circle the names of women who have made important mathematical contributions.

Maria Cibrario	Frances Drake
Maria Gaetana Agnesi	Marquise du Châtelet
Rosalyn Yalow	Pythagoras
Emmy Noether	Marie Curie
Dorothea Dix	Clara Barton
Maria Pastori	Hypatia
Sophie Germain	Sophie Piccard
Paulette Libermann	Harriet Tubman
Jacqueline Lelong-Ferran	Sonya Kovalevsky
Persephone	Mary Somerville
Cathleen Morawetz	Ann Anastasi

FAMOUS WOMEN MATHEMATICIANS*

Do you know about these famous women mathematicians? Read these brief introductions and decide which two you'd like to know more about.

HYPATIA (375-415)

Although everyone who studies the history of mathematics has heard of Hypatia, no one knows very much about her. Apparently Hypatia was involved in a political/love triangle that resulted in her death in 415. Historically, she is best known for her philosophical works, yet we do know that in the mathematical arena, she was well respected by the mathematicians of her day. Much of her training she received from her father, Theon of Alexandria.

MARQUISE DU CHATELET (Gabrielle Emilie Le Tonnelier de Breteuil) (1706-1749)

The Marquise du Châtelet is a somewhat controversial figure in the history of mathematics. While her personal life was rather notorious, that seemed not to enter into the controversy. There is, though, a question as to the value of her contributions and her understanding of higher mathematics. Although she wrote a large volume on the mathematical principles of natural philosophy, it is unclear whether these were her own ideas or those of her teacher, Clairaut. In any event, it was uncommon for a woman of her day to be involved in any way with these concepts.

MARIA GAETANA AGNESI (1718-1799)

Agnesi's principal contribution to mathematics was a book that systematically outlined all that was known about mathematics at the time. Agnesi felt that mathematical knowledge was progressing quickly and that a newcomer needed a reference source in order to absorb all the latest 18th century discoveries. Calculus, for example, was in a very rudimentary state at that time.

SOPHIE GERMAIN (1776-1831)

Germain used a man's name on the papers she submitted to her mathematics professors. When a prize was offered for the best essay on the mathematical theory of elastic membranes (which vibrate according to mathematical

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*Written by Elenor Rubin Denker.

laws), Germain submitted a solution, although most of the mathematicians at the time felt the theory was too difficult. In fact, she entered the same competition three times and did receive an award for the third entry, which was the only one submitted in her own name.

MARY SOMERVILLE (1780-1872)

At the age of 92, just before she died, Somerville was studying "Higher Algebra and the Calculus of Quaternions." Much of her writings were translations of the works of French mathematicians, specifically Laplace, who said that Mary Somerville was the only woman who understood his work. She wrote numerous books of her own as well, including one on physical geography and another on molecular and microscopic science.

SONYA KOVALEVSKY (1850-1891)

Kovalevsky has been called the most glamorous woman mathematician who ever lived. She was born in Russia in 1850 and later wanted to study at a foreign university. She did what many other women did at the time--married a young man who was going to study abroad and could take her with him. Since she was a woman, she couldn't attend lectures, so she had private lessons. Even when she received her doctorate, it was in absentia, because women could not attend the ceremonies. One of Kovalevsky's greatest recognitions came when she was awarded the Prix Bordin, the most prestigious award of the French Academy, for her work "On the Rotation of a Spatial Body about a Fixed Point."

EMMY NOETHER (1882-1935)

According to Albert Einstein, Emmy Noether was the most "significant creative mathematical genius thus far produced since the higher education of women began." Dr. Noether was born in Germany and lived there most of her life. Her family was mathematically inclined--her father was a well-known mathematician and her brother, a math professor. She developed slowly and began publishing major creative ideas only when she was almost 40. Up to that point, her papers, mostly on algebra, were more formal and less abstract.

MARIA CIBRARIO (1905-)

Maria Cibrario was born in Turin, Italy, at the beginning of this century. She studied math at the University of Turin and has spent most of her life as a professor of mathematics. She has done some of her works in collaboration with her husband, Silvio Cinquini, who is also a mathematician.

SOPHIE PICCARD (1904-)

The Piccard family left Russia in the 1920s and moved to Switzerland. Sophie Piccard found it difficult to find a teaching job there, although she had numerous advanced degrees. However, while she worked in other areas, she continued her research, which has been prolific, particularly her work on set theory and group theory. Since 1943, she has been a full professor of higher geometry and probability theory.

JACQUELINE LELONG-FERRAND (1918-)

As a child, Jacqueline Lelong-Ferrand received first prize in a national mathematics competition. She then entered one of the best high schools in France, at a time when women were just beginning to attend these schools. She has had a remarkable career, mostly in France, although she has also spent some time with her husband and children at Princeton.

MARIA PASTORI (unknown)

Maria Pastori and her sister Giuseppina showed a great determination in obtaining their education. As children in a large family of modest means, they were expected to go to work as soon as they finished elementary school. With some help from one of her teachers, and hours of study with her sister, Pastori managed to become one of only three women who presently hold full professorships in mathematics at leading Italian universities. Dr. Pastori is known for her work in tensor calculus, which is important for the understanding of dynamics, hydrodynamics, and elasticity.

PAULETTE LIBERMANN (1919-)

Dr. Libermann is a contemporary scholar in France, working in the realm of pure mathematics. Algebraic topology is her main area of interest, and a development of her undergraduate work at Sèvres. Much of her work is related to Einstein's discoveries.

CATHLEEN MORAWETZ (1923-)

In 1946 Cathleen Morawetz moved to New York and tried to find a job. She already had a Master's degree in mathematics from MIT, but jobs were difficult to find. Through her father, who was a well-known mathematician, she finally got a job editing a book on shock waves. Eventually, this was the subject of her Ph.D. thesis. Her research was directly related to the way airplane wings are designed.