American women mathematicians in the last quarter of the 19th century

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Abstract

By the last decades of the 19th Century, the North-American scientific community had begun to not only supplement the traditional undergraduate colleges by graduate schools in general, but also by promoting research and the training of future researchers in particular. The introduction of the doctorate degree signified the achievement of original research work and implied the capability for further production and also became a foremost requirement for entrance into the professoriate. Regarding science in general and mathematics in particular, this development within higher education produced useful results.
This timeliness proved to be even more crucial for the entering of women into the mathematical community. It was no mere coincidence that women contributed at all levels of the American mathematical community in the last quarter of the 19th Century. The time was indeed ripe, since three efforts converged in this period to create productive conditions for women in mathematics:
1. More than hundred years of advocacy and advancement in women's education culminated in a general opening of graduate schools and subsequent awarding of doctorates to women.
2. Women desirous of active participation in the mathematical community not only possessed the intellect but also the stamina to withstand the hardship of being the first ones.
3. Women operated in an arena with many influential mathematicians and others who not only sympathised but also supported their active participation.

Introduction: Mathematics in the North-America

When Annie MacKinnon, who was one of nearly a dozen American women who would make their way to Göttingen to study mathematics, wrote to Felix Klein in Göttingen in 1894, institutional mathematics in the United States was organized essentially as it is today, although on a much smaller scale. Prior to 1875, although research was considered prestigious within the growing scientific community, there were no institutional mandates and few institutional facilities for research. Furthermore, since there was little training in science beyond the undergraduate level, anyway, few people were able to reach the research level in their chosen discipline. Virtually only those who chose to study abroad, although there were notable exceptions to this, could get the extra training they needed to become productive researchers. All of this began to change after 1875 with the founding of the Johns Hopkins University. Although they only gradually replaced the more traditional view of the liberally educated scientist, a key turning point came in 1876 with the opening of the Johns Hopkins University according to the vision. The Johns Hopkins thus became a model for others to follow. New schools like Clark (opened in 1889) and the University of Chicago (opened in 1892) took graduate education and original research as part of their mission from the outset. Older institutions such as Harvard and Yale successfully moved with the changing times. Relative to science in general and mathematics in particular coupled with the overall trend toward

professionalization, differentiation and specialization within the broader scientific context produced scientific results during the closing quarter of the 19th Century. Opportunities existed for first class graduate work, and professional journals and societies had been established. Degrees listed as Ph.D.'s in mathematics had been given since 1862 by Yale and since 1873 by Harvard. When the British mathematician J. J. Sylvester accepted an appointment to the first professorship of mathematics at the newly founded Johns Hopkins University in 1876, he adopted a country in which mathematics at a research level had essentially gone uncultivated. Gilman, who was first president of Johns Hopkins, realized that for his new university to survive and prosper, it had to offer something different within the context of American education. As a result of his observations abroad, Gilman recognized that the United States trailed far behind the European countries in offering advanced training in the theoretical as well as in the practical sciences. Thus Johns Hopkins stressed graduate education, but not at the expense of undergraduate studies, and it made research and publication institutionally sanctioned. One of its goals was to make the United States competitive with Europe at the research level. Although American institutions of higher education had included mathematics in their curricula from the beginning, the level of sophistication of their programs only rarely exceeded that of the calculus throughout the 19th Century. Although efforts to sustain specialized mathematical journals had repeatedly been mounted, they had inevitably failed due both to a scarcity of interested subscribers and to a dearth of qualified contributors.

Research, publication and the domestic or better foreign doctoral degree increasingly separated the true scientist from the amateur.

The adoption of this latter credential, the doctorate, went hand-in-hand with the post-1850 developments in American higher education. As educators cast about for ideas to improve their institutions, they looked to Europe and particularly to Germany and borrowed ideas like *Lehr-* and *Lernfreiheit* which they then molded to fit their American needs. Furthermore, by the century's closing decades, they had begun to stress not only graduate education in general but also research and the training of future researchers in particular. The Ph.D. signified the achievement of original research work, generally of a highly specialized nature, and implied the capability for further production. Also, since only those who had actively contributed could possibly train those who aspired to this end, the doctorate became a foremost requirement for entrance into the professoriate.

These ideals of specialized graduate training culminating in the doctoral degree, together with original research, certainly took neither American science nor American higher education by storm.

The final decade of the 19th Century marked an incredible period of growth in American mathematics. During this time advanced mathematics including mathematics at the research level, firmly took hold in many American universities. No longer did college mathematics mean merely arithmetic, trigonometry, the rudiments of algebra and geometry, and a smothering of calculus. No longer were American students essentially forced to travel to the great universities of Europe if they wished to study the modern advances in mathematics seriously. Whereas in the 1870s they would have been limited to working at Harvard, Yale or Johns Hopkins, more American universities could now boast able research mathematicians. In the 1870s and 1880s mathematics had been born on the North American continent through the efforts of men like J. W. Gibbs of Yale, B. Peirce of Harvard and J. J. Sylvester of John Hopkins, but rapid growth during that period had

been an impossibility. Since the American educational system had only begun to offer more advanced training in mathematics, the level of sophistication of the students had not reached sufficient heights.

Women in the North-American Mathematics

It was no mere coincidence that women contributed at all levels of the American mathematical community in the last quarter of the 19th Century. By this time women had gained access to both undergraduate and graduate education in mathematics. Few established coeducational colleges admitted women before 1900. Since most American graduate schools were patterned after the German universities, which had introduced the Doctor of Philosophy degree in the eighteenth century and had never admitted women, American deans also rejected coeducation at the graduate level for several decades. Many schools began reluctantly to admit women, but did not include them in their college catalogs until later. Women were often admitted only in *special circumstances* or with *special permission* and were treated as if they were not attending the college. One notable exception is the University of Chicago, which, from its founding in 1892, admitted women on an equal status with men. From about 1870 on, a variety of opportunities existed for a woman to obtain a substantial undergraduate education. Private, especially church-related, coeducational colleges proliferated throughout much of the country after mid-century; by 1870 almost all the land-grant colleges and the state universities of the Mid-west were open to women; early female seminaries of the South were maturing into semi-colleges; and women's colleges opened in the East, beginning with Vassar in 1865. Beginning with Vassar College, women's colleges played an increasing role in the future of women's scientific education. These colleges were important for two reasons: (1) they were among the first colleges to award undergraduate degrees to women; and (2) they were among the first colleges to hire female faculty members. Whereas the more traditional four-year colleges felt that admitting women as students was heresy, women's colleges were accepted into society because they were promoted originally to make women better wives and mothers. Emma Hart Willard convinced conservative members of society that education for women would positively reflect upon their life skills and morality. She was the first of several pioneers who, despite their own lack of education, did much to increase the opportunities and raise the level of education available to the next generation of American women. Willard succeeded because she stated the case for women's education using many of the existing sexist notions about women's roles in society. She argued that women needed education to raise sons that were moral and had character. Many women were not doing a *good job* of raising their sons, so having an education would help them. By using these arguments, she convinced the conservative members of the government to support women's education, at least in the abstract. It is unfortunate she had to use such means to help the case for women's education. Others had a more direct influence on women's education. For example, Mary Lyon founded the Mount Holyoke Seminary for women. It later became Mt. Holyoke College, and employed many female faculty members as well as educating dozens of women. In addition to Mount Holyoke, the founding of Vassar College by Matthew Vassar, a forward thinking individual who felt that women should be educated, had a large impact on women's education. Furthermore, other women's colleges were formed after 1870, and played an important part in women's education. They include the following: Smith College, 1871, Wellesley College, 1875,

Bryn Mawr College, 1885, Baltimore College for Women. One of the other important features about the rise of women's colleges was their employment of female mathematicians as faculty members. In general, female scientists and mathematicians were most often employed in the academic community rather than in industry. At women's colleges, a female mathematician was more likely to become a department head than if she worked at a traditional college. By the early 1890s, several coeducational schools had graduate programs in mathematics, and a few traditionally male institutions admitted women at the graduate level only. Ostensibly dedicated to the equal education of young women, the women's colleges fulfilled yet another important role by providing educated women the opportunity for college-level teaching and research: consonant with the educational progress of the day, especially with regard to the doctorate as the increasingly important professional credential, the standards for faculty positions rose. The only way was for more women to obtain doctorates, and this could happen only if universities opened their doors to women at the doctoral level. In this time, however, most Ph.D. granting institutions in America and abroad did not support coeducation and so effectively blocked this educational avenue to women, but most was not all, and the few schools which did admit women at the graduate level, for example Bryn Mawr, Cornell, and others, set a pattern for other institutions to follow. That more and more graduate schools did change their policies and admit women students marked what has been termed *one of women scientists' greatest triumphs.*

The opening of the graduate schools began in the two decades preceding the 1890s with a phase of so-called *unrealized potential* during which women primarily gained admission thanks to a special students' status. This category of attendance allowed the student to sit in the lectures of a particular professor, usually without official admittance to the university, and hence, without eligibility to obtain a degree. An explosive period 1890-1892 followed when at least six prominent graduate schools: Yale, Brown, Columbia, Stanford and the universities of Pennsylvania and Chicago opened their doors to women. Yale and Pennsylvania allowed women into graduate school, but would not admit them as undergraduates and Columbia and Brown admitted women as graduate students, but allowed them as undergraduates only at a *coordinate college for women undergraduates*. Stanford and Chicago, however, allowed women full access to all aspects of higher education. Finally, from 1893 on the process entered an *embattled stage* when lagging universities not only admitted women to their graduate programs but also awarded them doctorates. Given the connections at the end of the 19th Century between the trends in higher education and the development of science in America, it comes as no surprise that the involvement of women in mathematics, in particular, closely paralleled this educational profile.

Equally as important as educational progress of the day were both the women who surmounted gender barriers and the men and women who encouraged them in their courageous pursuits. The women found their champion in Christine Ladd-Franklin. Capable, progressive and well acquainted with the task at hand based on own personal experience, Ladd-Franklin flourished in this role. She initially promoted women in mathematics from the inside as a student trying to bypass seeming inflexible rules by becoming an *exception*. When Ladd finished all of the requirements for the doctorate in 1882, Gilman refused to confer her degree. In reality, Ladd was only slightly ahead of her time. Ladd was halted but not defeated, and she began to direct her unique talents into the

more general effort for women in science and in particular in mathematics. Her focus thus turned to encouraging the effort from the slidelines rather than engaging as a player on the field. Though the details surrounding these earliest doctorates remain obscure, it is clear that Ladd-Franklin and the Association of College Alumnae (ACA) contributed, directly and indirectly, to many of the doctorates in the 1890's. The turning point for women in the United States to achieve academic recognition paradoxically proved to be realized abroad, at the Prussian University of Göttingen. Once again, Ladd-Franklin served as a catalyst. In 1891, she accompanied her husband to Germany for a year of sabbatical leave from his post at the Johns Hopkins University. She had hoped to use this opportunity to obtain the doctorate which Hopkins had denied her almost ten years earlier. However the climate in Germany in 1891 did not lend itself to the successful realization of her goal. During her year abroad, she succeeded only in auditing the mathematical lectures of Felix Klein. Still, both Felix Klein's sympathy and his assurances that *it was only the beginning for women at Göttingen* did provide cause for future optimism. In fact, Klein resolved to push the Prussian Ministry of Education by seeking out women who might be interested in pursuing a doctorate at Göttingen during his trip to the United States in 1893. Mary Winston, who attended the International Mathematical Congress and the Evanston Colloquium and who had just completed a year of graduate work at the University of Chicago and had then applied for a graduated fellowship at Wisconsin but was denied, presumably on the basis of her gender, met Klein during this visit. She had already decided that she wanted to study in Göttingen. After Klein determined that she was strong enough mathematically, especially in linear differential equations, he agreed to sponsor her admission to the university. Beginning with the winter semester of 1893-1894, several women also came to Göttingen to study with Felix Klein. The first were Mary Winston and an Englishwoman named Grace Chisholm. Both completed the entire dissertation work under Klein, effectively opening the door for foreign women to attend the Prussian universities. Grace Chisholm, who later married the English analyst W.H. Young, was said to have been Klein's favourite student. The letters she wrote home during this time vividly conveyed the excitement she felt as one of the first women to attend classes at a German university and under a great Professor. Winston first attended Klein's lectures and in December 1893, in Klein's seminar, she read a paper which later appeared in the *Mathematische Annalen.* Winston studied with Klein in Göttingen until 1896, finished her dissertation that year and received her Ph.D. in 1897. However most of the Americans who studied in Göttingen made at least one presentation in Klein's seminar, which was clearly one of the focal points of his teaching activity. These first women: Winston and Chisholm proved equal to the challenge, and their numbers grew to at least 14 by the winter semester of 1894-95. Seven of this total studied mathematics, astronomy and physics. Among these seven, at least Winston, Annie MacKinnon and Isabel Maddison had also studied in America. Having finished her studies at Cornell in the spring of 1894, MacKonnin attended Göttingen as the 1894-95 ACA European Fellow. In a letter of introduction to Klein in July 1894 she summarized her understanding of the opportunities for women at Göttingen. Isabel Maddison, on the other hand, hailed originally from England and scored as the 27^{th} Wrangler on the Mathematical Tripos in 1892. Moving on for graduate studies at Bryn Mawr, she won the first Mary E. Garrett European Fellowship in 1894-95 and continued her work at Göttingen. These pioneers: Winston, MacKinnon,

Maddison and others not only had their gender in common but also a mutual interest in mathematics.

By the end of the 19th Century, about 160 Ph.D.'s had been granted to Americans in mathematics. Johns Hopkins, which had produced 30 Ph.D.'s in mathematics before 1900, by far the most, was closed to women. Yale was second in the production of mathematics Ph.D.'s in that period with 23; the graduate school there was opened to women in 1892. Clark and Harvard were the next leading producers with 11 and 10 respectively, and neither granted Ph.D.'s to women.

American Mathematical Community and Women

When T. Fiske, E. Stabler and H. Jacoby of Columbia College solicited interested parties to meet on November 1888 to discuss the feasibility of forming a New York Mathematical Society, only three other people answered their call. Undaunted, by year's end these six enthusiasts had met again, adopted a constitution, and launched their fledgling organization. In an effort to increase their membership, they decided to target not only mathematicians living in and around New York City but also teachers of mathematics, engineers and others who might share their mathematical interests. Their recruitment strategy resulted in their growth to 16 members by the end of 1889 and to 23 by the close of 1890 and the first number of Bulletin of *the New York Mathematical Society* appeared in October 1891. Coming out monthly throughout the academic year, the Bulletin sought not to compete with journals like *Annals*, but rather to supplement their more properly research-oriented offerings with historical and critical articles, accounts of advances in different branches of mathematical science, reviews of important new publications and general mathematical news and intelligence. To this end, it carried such articles as *Kronecker and his Arithmetical Theory of Algebraic Equation* by H. B. Fine, reports like that of A. Ziwet on *The Annual Meeting of German Mathematicians* and reviews such as *Edwards' Differential Geometry* by Charlotte Angas Scott of Bryn Mawr. For the first two and one-half years *the New York Mathematical Society* had no women members, but the desire to publish a journal, the Bulletin, provided impetus for a major membership drive. Hence in 1891, the first six women joined the NYMS. The first was Charlotte Scott of Bryn Mawr, who became one of the most active and recognized women in the early history of the Society. Women not only joined the Society, but they participated actively in its meetings. The first paper presented by a woman, "An orthomorphic transformation of the ellipsoid", was read at the October 1892 meeting by E. C. Williams, a new member and teacher in a private school in New York, who had studied at Bryn Mawr, Cornell, Michigan and Newnham College at Cambridge and privately with H.A. Schwarz at Göttingen.

In connection with the World's Columbian Exposition, an International Mathematical Congress was held in Chicago in 1893, the year after the University of Chicago had opened. Among the forty-five whose names appear on the official register of the Chicago congress are four women. The listing includes Mary Winston and Ida May Schottenfels. Winston, as we saw, received a Ph.D. as a student of Felix Klein at Göttingen, having been one of the first three women who were officially admitted as regular students in a university administrated by the Prussian government. Schottenfels was a regular contributor to sessions at Society meetings and published in the Bulletin, the

Annals and the Monthly. She continued presenting papers to the society in some years later.

Women were part of the young and vigorous American mathematical community at the time of the founding of the society. Indeed, women have made contributions to mathematics through their research, their teaching, their service to the professional associations, and their participation in the mathematical activities of the larger society. While women have consistently maintained a presence within American mathematics, their numbers and their influence have not increased steadily over the years. The growth of the community of American women mathematicians roughly paralleled that of the larger mathematical community. By 1888, the year in which the society was founded, American women were already relatively active in mathematics. At Wellesley College there was an entirely female mathematics department. Bryn Mawr College had been in existence for three years and from its outset had offered fellowships for graduate study in mathematics and Charlotte Scott was head of the Bryn Mawr department of mathematics. Although educated at Girton, the women's college at Cambridge, Charlotte Scott attended lectures by Arthur Cayley at Trinity and effectively did her graduate work under him. Since Cambridge refused to confer degrees upon women at this time, Scott received both her Bachelor of Science in 1882 and her Doctor of Science degrees from the University of London in 1885. Immediately upon earning this latter credential, M. Carey Thomas lured Scott to America with a position as head and sole member of the Mathematics Department at Bryn Mawr College. While there, Scott advised seven doctoral students, received the college's first endowed chair on the basis of her fine teaching record, and, in general, according to the directors of Bryn Mawr College, made contributions *second only to that of President Thomas* during her 40-year tenure at the school. Her early doctorate in mathematics served as one of the initial ripples with Scott's high and uncompromising standards perpetuating the effect. Furthermore, her influence seemed largely independent of her womanhood. Scott steadfastly refused to set herself apart on the basis of gender. In fact, Scott believed that *intelligent men would give her sex the credit that is due*. The AMS justified this belief for, on the basis of her talent and energy, she became a relatively important force within the Society. By holding such important and visible positions, Scott undoubtedly encouraged women to participate in the mathematical community. In fact, the lives of Scott and Christine Ladd-Franklin reflect the two most potent tactics employed by the promoters of women in mathematics. Using a direct, forceful, and more externalized approach, Ladd-Franklin fought hard to gain ground for women. Although herself in the academic arena in the earliest stages of the effort, her greatest influence came later and from the outside of academe in the broader political sphere of the growing women's movement. She viewed the entry of women into mathematics as part of a much larger social issue and attacked it as such. By providing both financial and emotional support for those actively pursuing degrees, Ladd-Franklin substantially improved the climate for women in mathematics. Charlotte Scott, on the other hand, propelled women forward using more discreet methods. In striving for the highest standards in mathematics, both in terms of teaching and research, she advanced within the mathematical ranks, thereby gaining an otherwise unheard of position for women. Her uncompromising standards and her steadfast refusal to expect less of a women than of a man in the academic realm both challenged and advanced women in her field. During the course of their careers, many of Scott's male counterparts in the AMS supported women in mathematics as well.

With so many influential AMS members and other prominent mathematicians like Sylvester and Klein supporting the notion of women in mathematics, with Charlotte Scott setting the percent for the possibilities available to women, and with the groundwork laid and supported by Ladd-Franklin and others, it would appear that the turn-of-the-century mathematical community was, indeed, hospitable to women. The women in the American mathematical community enjoyed a most unusual environment compared to the other professional organizations of the day.

Just as activity did not necessarily go hand-in-hand with a doctorate, it did not depend upon employment at an institution of higher education either. Ida May Schottenfels presented 17 papers and published three, making her second only to Charlotte Scott in this category of participation. Schottenfels's highest earned degree, however, was a Master's and she spent her teaching career at grammar and high schools in Chicago and the New York State Normal School.

Active high school teachers also emerged among the mathematically interested. Teacher memberships indicate that the Society did not limit itself to women whose mathematical interests fell only within the confines of collegiate teaching and research. Furthermore, a developing interest in mathematical pedagogy at the turn of the century introduced some participants to the American mathematical community who were otherwise beyond the typical bounds of the AMS in terms of membership.

Conclusion

The women of this study frequently took advantage of the unique circumstances in which they found themselves. They broke into the academic work force at both women's and co-educational institutions; and they participated in the newly forming American mathematical research community. While certainly neither as numerous nor on the whole as productive as their male counterparts, women nevertheless formed a vital and visible contingent within the last quarter of the 19th Century American mathematics.

References

- Burchsted, Frederic F., "Sources for the History of Mathematics in the Archives of American Mathematics", A Century of Mathematics in America, Vol. III, edited by P. Duren with the assistance of Richard A. Askey, Uta C. Merzbach, 1989, American Mathematical Society, pp. 667-673.
- Fenster, Della D., Parshall, Karen H., „A Profile of the American Mathematical Research Community: 1891-1906", the History of Modern Mathematics, Vol. III, Knobloch, E., Rowe, David E., 1994, Mathematical Progress in America, pp. 179-227.
- Fenster, Della D., Parshall, Karen H., „Women in American Mathematical Research Community: 1891-1906", the History of Modern Mathematics, Vol. III, Knobloch, E., Rowe, David E., 1994, Mathematical Progress in America, pp. 228-261.
- Fiske, Thomas S., "Mathematical Progress in America", A Century of Mathematics in America, Vol. I, edited by P. Duren with the assistance of Richard A. Askey, Uta C. Merzbach, 1989, American Mathematical Society, pp. 3-17.
- Green, J., LaDuke, J., "Women in the American Mathematical Community: the Pre-1940 Ph.D.'s", The American Intelligencer, Vol9, No. 1, 1987, Springer-Verlag New York, pp. 11-23.
- Green, J., Laduke, J., "Women in American Mathematics: A Century of Contributions", A Century of Mathematics in America, Vol. II, edited by P. Duren with the assistance of Richard A. Askey, Uta C. Merzbach, 1989, American Mathematical Society, pp. 379-398.
- Kenschaft, Patricia C., "Charlotte Angas Scott (1858-1931)", A Century of Mathematics in America, Vol. III, edited by P. Duren with the assistance of Richard A. Askey, Uta C. Merzbach, 1989, American Mathematical Society, pp. 241-252.

- MacLane, S., “Mathematics at the University of Chicago, A Brief History”, A Century of Mathematics in America, Vol. II, edited by P. Duren with the assistance of Richard A. Askey, Uta C. Merzbach, 1989, American Mathematical Society, pp. 127-154.
- Merzbach, Uta C., “The Study of the History of Mathematics in America: A Centennial Sketch”, A Century of Mathematics in America, Vol. II, edited by P. Duren with the assistance of Richard A. Askey, Uta C. Merzbach, 1989, American Mathematical Society, pp. 639-666.
- Parshall, Karen H., Rowe, David E., “American Mathematics Comes of Age: 1875-1900”, A Century of Mathematics in America, Vol. III, edited by P. Duren with the assistance of Richard A. Askey, Uta C. Merzbach, 1989, American Mathematical Society, pp. 3-28.
- Parshall, Karen H., “Elikan Hastings Moore and the Founding of A Mathematical Community in America: 1892-1902”, A Century of Mathematics in America, Vol. II, edited by P. Duren with the assistance of Richard A. Askey, Uta C. Merzbach, 1989, American Mathematical Society, pp. 155-175.
- Richardson, R. G. D., “The Ph.D. Degree and Mathematical Research”, A Century of Mathematics in America, Vol. II, edited by P. Duren with the assistance of Richard A. Askey, Uta C. Merzbach, 1989, American Mathematical Society, pp. 361-378.
- Smith, Percey F., “The Department of Mathematics”, A Century of Mathematics in America, Vol. II, edited by P. Duren with the assistance of Richard A. Askey, Uta C. Merzbach, 1989, American Mathematical Society, pp. 121-126.