NOTABLE ENGINEERS: A PROJECT BOOK

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Abstract *– Typically, teachers and counselors for grades 7-12 are not sufficiently educated in the areas of engineering to provide information and guidance to students. In addition, unconscious gender-related behavior by teachers in the classroom can dissuade female students from considering engineering even when there is an increased awareness of the discipline. Nationwide, there is a growing need for students to choose engineering as a profession, and to respond to the demands of an ever-increasing technology oriented society. Therefore, encouraging women in engineering and providing all students with a respect and history of women engineers are beneficial to all.*

This paper reports on a project designed to disseminate information about engineering through experiments and biographies of engineers in a format that can be integrated into the existing 7-12 curriculum. Each experiment is linked to an engineering discipline, which in turn is linked to an engineer in that field. The engineers selected are all women, and presented as matter-of-factly as resources that highlight all male engineers.

Index Terms – engineering biographies, engineering history, K-12 engineering education, women in engineering.

INTRODUCTION

Nationwide, university programs have addressed the challenge to recruit female students into engineering with summer camps, workshops and informational seminars for students. While it is true that these programs generate interest in engineering among female students, there is little evidence that they contribute to a student choosing a science or engineering major [1]. Teachers have regular access to students and can influence some of the most important factors that contribute to students majoring in science and engineering. These factors include students: being in the academic track, taking the most demanding science and mathematics courses, early research participation, having a good, enthusiastic science teacher and/or guidance counselor, participation in an intervention program, and being in a science-intensive school [1]. The role of teachers is critical to maintaining females' interest in Science, Technology, Engineering and Mathematics (STEM) and to recruiting students into engineering. Teachers have the potential to affect significantly the career direction of their students. Yet, "in the physical sciences … almost half of American students are taught by teachers without a major or minor in that field" [2]. Additionally, a Harris Poll survey released in 1998 showed "45% of Americans feel uninformed about engineering and engineers" [3]. Clearly, engineering educators can play an important role in educating teachers about ways of teaching science and informing students about engineering.

An engineering project book for teachers in grades 7-12 is being written. It includes the biographies of historical women engineers in the areas of electrical, computer, mechanical, civil, environmental, and industrial. The amount of written works about historical engineers lags far behind that of women scientists and mathematicians; however, some ongoing research such as in [4] provide starting points for this material. Some current women engineers are highlighted as well. Descriptions of suggested projects will relate to each role model's work and provide hands-on learning of math and science.

Sixteen notable engineers were chosen for the book: Barney, Baum, Clarke, Dresselhaus, Eaves, Fu, Gilbreth, Gleason, Hopper, Lamme, Lovelace, Resnik, Richards, Roebling, Silbergeld, and Walton. Thirteen of their abbreviated biographies are the subject of the following sections.

NORA STANTON BLATCH BARNEY

Nora Stanton Blatch Barney led a dual life, that of engineer and women's rights crusader. In addition to her accomplishments in these areas she also raised a family. Her accomplishments as an engineer are often overshadowed by her work for women's rights [5].

As an engineer, Blatch was the first woman in the United States to receive a degree in Civil Engineering. She earned a B.C.E. in 1905, cum laude, at Cornell University. In the same year she became the first woman member (junior status) of the American Society for Engineers (ASCE). Fresh from college, she had written a paper on the water supply of Washington, DC. This paper was a primary reference for studies on the transport of solids in liquids for over fifty years [6].

After Cornell, Blatch, she continued her studies at Columbia University. Blatch worked as an engineer and draftsman for the New York Public Service Commission and for the Radley Steel Company. She seemed to drift from pure engineering to architecture. This may have been because architecture was less of a "man's world" and more accepting of her. During the depression, she was called upon to be an engineer and architect for the Public Works Administration in Connecticut and Rhode Island.

Nora Blatch Barney was a third generation activist for women's rights. Her grandmother was the famous Elizabeth Cady Stanton. Stanton devoted her life to the rights of women and the abolition of slavery. She helped organize groups for these causes and had several publications [5].

In 1916, Blatch Barney applies for full membership in the ASCE. She was unsuccessful even after legal action. At this point she was not allowed to remain a junior member. It was eleven years before Elsie Eaves became the first full member of the ASCE [6].

ELEANOR BAUM

Eleanor Baum stands out for her success in getting women to choose a career in engineering. First, she is a living example. Also, six times more women are in engineering at Cooper Union, since she started as Dean.

Baum was born in Poland just before World War II began. Her family had to flee the Germans and Russians. Their escape story would make a good movie. By the time she was three her family were in New York City [7].

She attended public schools and did well. She took some advanced science and math classes. She enrolled in City College of New York. She chose electrical engineering as a course of study. Her mother wanted her to be a teacher. The mother feared no one would marry a female engineer. At City College, Baum found many of the teachers to be insensitive. Some were even worse. She was often the only woman in her class. Her teachers and classmates thought that some things "could not be understood by a woman." Baum finished the five-year program in four years [7].

After college, Baum worked in the aerospace industry for a short time. She found the work boring and frustrating. She received a fellowship to return to college. While in graduate school, she was required to teach a class. Surprisingly, she really liked to teach. In time, she and her husband both decided to quit their jobs and teach. At Pratt Institute, she rose from assistant professor to dean of the department. For almost 20 years, she helped students break out of the poverty around Pratt.

In 1987 she was recruited to be dean of the Engineering College at Cooper Union. When she started, women made up about 7% of the enrollment. There were almost no minority students. In seven years women made up 30% and minorities made up 11%. These numbers are still growing [7]. Dr. Baum also works to improve opportunities for women through the American Society for Engineering Education [8].

EDITH CLARKE

Edith Clarke was a highly regarded electrical engineer in the field of electric power. Her work was the basis for putting large power supply systems on a solid mathematical basis.

Clarke's early education was typical. She was taught music, literature, languages and some math. She then went to Vassar College. She graduated with very high honors. At Vassar, she studied math and astronomy. When she went to Vassar, it did not offer courses in engineering [9].

After college she taught math and physics in girl's schools for a few years. Next she took classes at the University of Wisconsin to study engineering. After one year she got a job with AT&T as a "computer." Clarke was very skilled and was put in charge of the other computers. She was in charge of calculations in the transmission department at AT&T [10].

Clarke wanted to be an engineer so she left her job and enrolled at MIT. She earned a MS degree in 1919. This was the first time a woman had earned a MS degree in engineering at MIT. She went to work at General Electric (GE) in charge of "human" computers. In 1921 she filed a patent for her "graphical calculator." This invention made calculations easier and faster [11].

In 1921 and 1922 Clarke went to the country of Turkey to teach physics. She taught at the Constantinople Women's College. When she returned to the United States, she went back to work for GE. This time, though, she was an engineer, and she worked there for another twenty-five years. While at GE she received two more patents. She was considered one of the best in her field [11].

At an age when most people retire, Clarke became an engineering professor at the University of Texas. This was the first time a woman was a professor in engineering at Texas. She taught for 10 years [9].

MILDRED SPIEWAK DRESSELHAUS

Mildred Dresselhaus is a prominent electrical engineer. She is known for her cutting-edge work in semi- and super-conductor research. She is an educator and researcher.

Dresselhaus was born Mildred Spiewak in a very poor area of New York City. Her immigrant parents had to struggle to keep their family fed during the Great Depression. Dresselhaus realized that education would be her way out of poverty. When she was eleven she took a job teaching a child with mental retardation to read and to write. This inspired her to become a teacher. She excelled in her schoolwork and developed a love of science [12].

To become a teacher she went to Hunter College. Professor Rosalyn Yalow steered her toward physics, Yalow later became a Nobel Prize winner. Dresselhaus oobtained her Masters' degree in physics from Radcliffe. She received her doctorate from the University of Chicago and later did post-doctoral work at Cornell [13].

Dresselhaus and her husband both got hired at Lincoln Laboratory. After seven years in the lab, she received an endowment to teach at MIT and became the first woman to tenure in MIT's engineering department. She also teaches in computer science and physics [7]. In 2000, Dresselhaus was named to head the Science Office of the US DoE [14].

In addition to research, Dresselhaus has also worked to improve opportunities and acceptance of women in the sciences. MIT had a six percent enrollment of female students. Numbers have risen dramatically according to Dresselhaus. She relates that there was discrimination but there were also opportunities. There were twists and turns in her career to take advantage of opportunities [7].

ELSIE EAVES

Elsie Eaves was born just before the turn of the last century. She obtained her Civil Engineering degree from the University of Colorado at Boulder. Then she worked for the US Bureau of Public Roads and the Colorado Highway Department. She also worked for the Denver and Rio Grande Railroad. Eaves was elected to the American Society of Civil Engineers (ASCE) in 1927 as a practicing civil engineer. She was the first woman to be a full member [5].

Eaves entered the publishing world around 1927. At first she was and assistant manager for market surveys. This was for *The Engineering News and Report*. In 1945 she began managing *Business News.* Eaves developed measurements for the construction industry. She used these for news reports. Her reports were used by the government and to speed up post-war construction. Her statistical analysis are part of the basis of current cost accounting. She devised indexes and looked at cost trends. Today, consumers and builders benefit from her methods [10].

After retirement, Eaves became an advisor. She advised on housing costs to the Commission on Urban Affairs. She advised on construction costs in Iran. This was for the International Service Corps [15].

Like many women engineers in this era, Eaves was a systems thinker. She looked at the overall picture. Elsie Eaves has had a lasting influence on cost engineering.

In 1979 she was given the highest honor by the ASCE. She was named and "honorary lifetime" member. She had received the Norlin Medal. This is the highest alumni award from the University of Colorado [15].

BEATRICE FU

Beatrice Fu works at the cutting edge of computer technology. She has had to overcome many obstacles.

Fu is a computer engineer. She is highly respected in the field. She credits her success to flexibility and determination. She graduated from CalTech in 1980. Only about one in ten of the students were female. Most of them were in biology. When told that engineering was not for women, she took it as a challenge. At CalTech she studied aerodynamics and applied math. Next, Fu attended Berkley. There, she studied Mechanical Engineering. In 1981, she finished her master's and went to work for Intel [7].

Fu had little background in computers. With a strong background in math and basic technical skills, she adapted quickly. Fu worked her way up at Intel. She first worked with transistors. Later, she helped develop a software compiler. By 1995, she was the director of over 200 engineers at four different sites [7]. In 1998, Fu joined the new company, Tensilica in charge of the engineering department [16].

Fu had two obstacles, being a woman and being Asian. Because she was a woman, her culture objected to her going to college. Even in the US, she was told that engineering was not for women. This was only 20 years ago! Fu feels that as she advances, it gets harder for a woman to advance. Being Asian makes it even harder. She said that in industry, one is judged by white men. You must be able to communicate with them to advance [7].

LILLIAN MOLLER GILBRETH

Lillian Moller was born to a prominent California family. Her father did not think college was appropriate for her or most women. She was able to convince him to let her attend the University of California at Berkley while staying at home. She graduated with honors in 1900 and became the first female to make a commencement address at that university. She continued her study of literature at Columbia University for one year but then due to illness returned to California and Berkley. After completion of her Masters in Literature she met and married Frank Gilbreth in 1904 [17].

Frank brought Lillian into his quest for the "One best way" to complete a task and to manage others. She was an avid student and quick learner. She helped him write and publish articles on motion studies and management [18]. To better understand how workers' and managers' mental attitudes influence their work, Gilbreth began working toward a Ph.D. in psychology. She completed this in 1915. Her thesis "The Psychology of Management" was published and used as a reference for several years [10]. The Gilbreths combined their talents to form theories and practices that still influence the way Americans look at work tasks [18].

Lillian and Frank Gilbreth built an international company to help industry improve their operations. Unfortunately, Frank died in 1924 leaving a widow with twelve children and a business in the middle of several projects. Gilbreth quickly erased any doubts about her ability to take care of the family or the business. She continued publishing in the field of management engineering [13].

The family life of Gilbreths was celebrated in a book, *Cheaper by the Dozen*, written by two of their children. A popular movie was produced on the book. The Gilbreth management methods were applied in their household [10].

KATE GLEASON

Kate Gleason was one of the first women to study engineering in college. She was a "special" student in mechanical arts in 1884 at Cornell. At the same time she took classes at the Sibley College of Engraving and Mechanics Institute. Sibley later became the Rochester Institute of Technology. She did not complete a degree [19].

Gleason was the daughter of an owner of Gleason Works. The company made machining equipment. She began at age 12 working on Saturdays. Gleason helped her father design a gear-cutting machine that was very innovative. She drew the praise from Henry Ford for the new machine. Later, she moved into sales. After she became a director of the company, she started some new business

practices that took Gleason Works from a small factory to a national producer of gear-cutting machines [10].

Gleason left her family's company in 1913. She went to another machine company that was failing, and was guided the company out of debt. During World War I, Gleason became president of the Rochester National Bank. This marked the first time a woman held this title in a National Bank. After the War, she stepped down. During her time at the bank, Gleason started a low cost housing development. Later she started a development in South Carolina that her younger sister completed after Gleason's death [5].

In 1918, Kate Gleason became the first full member of the American Society of Mechanical Engineers (ASME) [5]. Kate Gleason was not the usual woman of the late 1880's and early 1900's. She was an industrialist, engineer, banker, and builder. Gleason saw that education has value. In her day formal schooling was not readily available to women. She left a large estate to the Rochester Institute of Technology. Their college of engineering is named in her honor. Part of her legacy is supporting higher education [10].

GRACE HOPPER

Grace Murray Hopper is one of the most important pioneers of the computer age. She had the foresight to make computers useful to everyone. Her "can do" attitude opened many doors. She has been called the "Grandmother of the Computer Age" and nicknamed "Amazing Grace" [20].

Grace Murray was born in New York to Walter Murray and Mary van Horne. Mr. Murray wanted his daughters to have the same education as his son. He said that education would let them take care of themselves. Mrs. Murray had a love of math. She was allowed to study geometry, but not algebra and trigonometry as these were not considered appropriate for a lady [21].

Hopper grew up with an inquisitive mind. She earned a B.S. in math and physics from Vassar in 1928, M.S. in math from Yale and Ph.D. in 1934 [22]**.** Hopper was hired as an instructor at Vassar where she continued until she entered the Navy in 1943. Her first assignment was to help figure firing solutions for the Navy's ships. This duty included working with the Navy's computer, Mark I, at Harvard. In 1945 while working on the Mark II, Hopper found and removed a moth from a relay. This is the first program "debugging" ever noted [23].

By the time Hopper retired in 1986 she was a Rear Admiral and the oldest active member of the Navy. In 1966 she was forced into mandated retirement because of her age. Within a few months she was called back to work on computer problems. Her skills and abilities were simply unmatched. The Navy needed her [24].

When most other experts thought computers would only be used by higher education and the government, Hopper's vision was that computers would have commercial uses. She knew computers would have to get easier to use. She developed a compiler, allowing the program to call for previous instructions, saving time and money, and reducing errors. Hopper also developed computer languages [11]. Her language was the basis for languages still used today. Yet, Hopper said that teaching was her greatest contribution [21].

BERTHA LAMME

Bertha Lamme obtained a BS in mechanical engineering with an option in electricity from Ohio State University. This was the first engineering degree to a woman granted by Ohio State, and the first US engineering degree outside of the civil and architectural fields. In 1893 Lamme was recruited by Westinghouse to work in their laboratories, but she was never allowed into the factories and workshops to see the results of her ideas and designs. This would certainly make her work much more difficult. Much of Lamme's work seems to have been mathematical calculations for machine design. She was known to be gifted in mathematics and, was fairly well known in engineering circles [10].

Westinghouse was on the cutting edge in the emerging field of electricity. They were developing alternating current (AC) systems to compete with the direct current (DC) systems of Thomas Edison. During Lamme's employment at Westinghouse, they obtained dozens of patents on groundbreaking inventions and devices for the generation and distribution of electricity [25].

Details about Lamme's specific contributions to the field of electrical engineering are very limited. The Westinghouse engineers worked and generated projects as a team. Also, at Westinghouse in this period were her brother, Benjamin Graver Lamme and her future husband, Russell Feicht. Benjamin Lamme was a renowned engineer and has a major IEEE award, Lamme Medal, named for him. When Lamme married Feicht in 1905, company policy required that one of the two would have to leave Westinghouse. In 1905, Lamme resigned to be wife and mother [10].

Ohio State named a laboratory after both, Bertha and Benjamin Lamme. This honor, combined with her long employment at Westinghouse, attests to her abilities as an engineer [11].

ADA LOVELACE

Augusta Ada Byron Lovelace was the first computer programmer. She lived one hundred years before the modern computer was even invented. Lovelace was the first woman to be a computer engineer.

Lovelace was the daughter of Lord Byron and Annabella Milbanke. Byron was a very famous poet and writer, but Lovelace's mother steered her toward mathematics. When Lovelace was growing up, few people went to school. She was well educated because she was from a very prominent family, and she had a respected mathematician, De Morgan for a math tutor. He never told her just how good she was. The tutor did not think women could hold up to the stress of being a mathematician. Besides math, she studied music and languages. Lovelace was

fascinated by mechanical things and had a knack with machines. At eighteen, she saw Charles Babbage's difference engine at a party. To Babbage's amazement the young lady understood his machine. This was the beginning of a livelong friendship and cooperation [26].

In 1842, L.F. Menabrea wrote a major paper in French analyzing the Analytical Engine. She translated it for Babbage and added many notes and examples. She wrote directions on how to set up the machine to do certain procedures. These directions were the first computer programming. Refined women did not write scientific papers, thus, Lovelace could not put her name on the paper, but signed it with her initials, AAL [13]. In her paper, Lovelace suggested the use of a binary storage system that is used in all modern computers. She also wrote test programs for Babbage's machines. she used loops, storage, keypunch, routines, and central processor 150 years ago [27].

The difference and analytical engines were made of wood and brass and looked like clock works. During Lovelace's time, machines were not capable of building accurate parts. The engines of Babbage could not be built to put her programs to work. If the machines could have been made and reproduced at that time, the computer age Lovelace envisioned may have come sooner [26].

Unfortunately, Ada's life was cut short. She died of cancer at the age of 36. In the 1980's the Department of Defense named its computer superlanguage *Ada* in honor of her contributions [13].

ELLEN SWALLOW RICHARDS

Ellen Swallow Richards was one of the most progressive scientist and engineers of the late 1800's. She had a broad range of competencies, including metallurgy, sanitation, ecology, and nutrition. A century ago, she was urging people to live in harmony with the environment. She made large and long lasting contributions to society.

Ellen Swallow was born to teacher parents in rural Massachusetts. By working as a tutor and at various jobs, she completed her A.B. at Vassar College in two years. She was admitted to MIT as a special student with her tuition waived [28]. Later, she learned this was not a scholarship but rather a way to avoid opening the door for more women students. After completing a B.S. she continued her studies but was not granted an earned Doctorate. Presumably, MIT did not want its first Chemistry Ph.D. to go to a woman [13].

Through her work with her husband Robert Richards, she discovered the rare ore, Samarskite and isolated the element Vanadium. She became the first female member of the American Institute of Mining and Metallurgical Engineers (AIMME) [5].

Ellen, using her chemistry background, began applying her skills to analysis of ground water and food quality. Her work in ground water analysis is the basis for much of our understanding of water quality. Another concern was air quality. Richards began analyzing heating and ventilation systems in building. She made herself an authority on food and the human diet. Her work was the foundation of the domestic sciences or home economics [10]. She was able to take findings from chemistry, food quality, air quality, and sanitation and put them to use to improve the health of society. In her day the home was a dangerous place.

Richards got funding for equipment for a Women's Laboratory at MIT in 1876, where she worked as an unpaid assistant. In 1884, She began teaching Sanitation Chemistry as an experimental offering. Over the next 27 years she taught the men who became known as the "father's" of their specific specialties in Sanitation Engineering [29].

With all of her foresight, groundbreaking work, and contributions to the sciences of sanitation, ecology, euthenics and mineralogy, Ellen Swallow Richards has been given little credit. Even with the educational, social, and professional obstacles faced by her, she excelled [10]. She was not only one of the few woman engineers of her day but rather one of the foremost engineers of that time.

EMILY WARREN ROEBLING

One of the greatest engineering accomplishments of its day, the Brooklyn Bridge, was completed under the supervision of Emily Warren Roebling. She was the first woman to be recognized as a field engineer in the United States. Roebling was the first woman to formally address the American Society of Civil Engineers [30].

Emily Warren was born to a family of some means and was considered "well-educated" for her time. She was literate, attended some school and probably trained in literary or musical fields. She did not attend a college or university. Even this amount of formal education was unusual for girls in the middle of the 1800's. Emily was also exposed to mathematics and engineering as a young lady as her brother was a mathematics instructor at West Point and an Army engineer [30]. Later, Emily continued her informal education, teaching herself higher mathematics, material strength, stress analysis, cable construction and bridge specifications. Even with some tutoring from her husband, most of her education would have been self-study [31].

In 1865, Emily Warren married a young engineer, Col. Washington Roebling. Emily's father-in-law, John A. Roebling was a well-known bridge builder who began work on the Brooklyn Bridge in 1869. As a result of an infection contracted from an injury at the construction site, the elder Roebling died. Col. Washington Roebling was named as the new Chief Engineer. In 1872, Col. Roebling got decompression illness from working in the pnuematic caissons. His speech, hearing, and mobility were very seriously impaired and kept him from ever returning to the bridge. He came to depend on his wife to be his go between for the construction project [10].

Mrs. Roebling directed the construction on a day-to-day basis earning the respect from workers and supervisors. She tactfully dealt with city officials and the public about cost

over-runs and delays. By demonstrating the knowledge and skills of a capable engineer and manager she earned the title of "Field Engineer" [32]. In 1882, Emily Roebling addressed the ASCE to defend her husband's performance and delays on the project. Because she was the field engineer, she was actually defending her own accomplishments. This speech was well received and she was allowed to continue and complete the bridge in 1883.

Little recognition has been given to Emily Warren Roebling, for her essential role in the construction of the Brooklyn Bridge. However, there is a plaque on both towers of the bridge honoring her and her accomplishments [10].

CONCLUSION

Admittedly, these highligthed engineers have made great contributions and make good role models for any future engineer. The fact that these outstanding engineers all happen to be women may especially cause some female students to consider an engineering major in college.

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17 Engineers apply techniques of engineering analysis in testing, production, or maintenance. Analytical engineers may supervise production in factories and elsewhere, determine the causes of a process failure, and test output to maintain quality. They also estimate the time and cost required to complete projects. Supervisory engineers are responsible for major components or entire projects. Engineering analysis involves the application of scientific analytic principles and processes to reveal the properties and state of the system, device or mechanism under study.

Greatest engineering books including the design of everyday things, zen and the art of motorcycle maintenance, machinery's handbook and homofaber.Â Whether for business or pleasure, we have compiled our recommendations for more than 30 of the greatest engineering books available. By Christopher McFadden. January 17, 2017. Chris Devers / Flickr. So, you want some recommendations for great engineering books? Then you've come to the right place. Following publications are recognized as some of the most remarkable engineering books of all time and many of them are enduring classics. The list is not exhaustive, but in our opinion, these are the greatest engineering books to buy (or borrow). 1. To Engineer Is Human: The Role of Failure in These projects demand that civil and structural engineers have the ability to handle the increasing difficulty in designing even more complicated projects such as tall buildings or structures with complex geometries. The effective design of these types of structures is based on a clear understanding of the behavior of the structures, relevant analysis theory, and method, knowledge of effective numerical modeling software, and of specific design principles.Â In most universities, the basic design modules are taught to students. However, it is hard to find a module that has a systematic introduction to the design and analysis of tall and complex structures. Therefore, a book in this area is imperative. Content : Introduction.