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Abstract

Do you ever feel there is a lack of recognition of women mathematicians? In this paper, we will be diving into Gertrude Blanch's contribution to the world of mathematics. She has strong connections in business and mathematics. She is known for being a leader of the Mathematical Tables Project (computing organization) and pioneered algorithm designs for humans and mechanical computers. Reading this paper will give you information about Blanch's designs and explanations of where she came up with the ideas and how they affected the future of mathematics.

Gertrude Blanch was a profound mathematician who made groundbreaking contributions to computer sciences and became an emerging woman leader when society was strictly male-dominated for positions of power. Allowing women admission to college and offering women professions with authority was rare in the early 1900s. Throughout the Great Depression, women scholars struggled to find professions that would use their degrees. Blanch overcame many obstacles in her lifetime involving poverty, war, and economic depression. She made impacts on the fields of algebraic geometry, differential equations, and natural logarithms, and was a leader in the Mathematical Tables Project. Gertrude Blanch is one of the last and most important leaders in human computers and can be considered one of the first numerical analysts for electronic computers (Grier, 1997). Unfortunately, her work is not known by many, but it continues to be studied by computer scientists and mathematicians today and paved the way for transitioning from hand calculations to computing machines.

Gertrude Blanch was born in Kolno, Poland in 1897. Her born name was Gittel Kaimowitz. Her entire family emigrated to the United States in 1907 and moved to Brooklyn, New York (Suzuki, 2009). Blanch attended schools in New York, where her father encouraged her to pursue an education in mathematics. Her teachers noticed her excellent abilities. When she was in elementary school, she claimed that she was going to be a mathematician. This seemed to be an unrealistic statement at the time because there were limited roles in this profession for women. Few schools encouraged women to study mathematics. Society wanted women to be able to use their knowledge and talents without disrupting the male dominance of professions and power. In the United States, there were at least a hundred female mathematicians who were demoted to limited roles (Grier, 2005). Blanch's father passed away in 1914, pressuring her to obtain a job where she could support her family. Blanch paused her education and became an office worker in Manhattan for 14 years, preparing Blanch for her role in the Mathematical Tables Project (Grier, 1997). During this time, U.S. businesses were rapidly expanding and testing new methods of organization, and by 1914, computation was emerging as a key business tool. Blanch's work in the business world gave her insight into the ideas of Fredrick Winslow Taylor, who started the first time-and-motion studies of industrial workers to advance labor efficiency. Taylor's work was incorporated into many of Blanch's key ideas with her future contributions to the Mathematical Tables Project (Suzuki, 2009).

Blanch's first clerical job was at Jacob Marks and Company. Here, Blanch did calculations including accounting, inventory, and planning, until she became manager (Grier, 1997). During her time as a manager, she set aside money hoping to still reach her goal as a mathematician. When her mother passed away in 1926, this gave Blanch the freedom to finally begin her professional studies as a mathematician. She began taking night classes at NYU, and after graduating, she left her clerk job to look for graduate schools. Many graduate schools did not offer women a place or scholarships. Blanch decided to attend Cornell University (Grier, 2005). She felt comfortable at Cornell, seeing few limitations of being a woman in mathematics. Blanch graduated during the greatest depth of the Great Depression when there were few jobs for mathematicians and fewer for women. This was when Blanch changed her name to sound more American, taking her mother's last name.

Blanch applied for another clerk job, answering an ad in the *New York Times* (Grier, 2005). While working as a manager of Barker Devin Company, Blanch enrolled herself in a relativity class with Arnold Lowan at Brooklyn College. Attending a few lectures but still managing professional homework responses caught Lowan's attention. Lowan was delighted to hear about Blanch's doctorate in mathematics and asked her to join his project, the Mathematical Tables Project, which was created in 1938 (Grier, 1997). Blanch would be a part of the project from the start until 1942. Blanch became the technical director and chaired the Planning Committee. Having a business and mathematical background allowed Blanch to excel in this position. The project started as a part of the Works Progress Administration (WPA), which funded the project to help support the crisis of unemployment (Formal, 2021). The project gave 150 unskilled workers a new profession of manual computing, using only paper and pencils. Blanch divided the computing floor into four different groups, one for each arithmetic operation. The Planning Committee would first translate the mathematical expressions used for the computations and a starting value for the table, using the Taylor series, continued fraction, or other kinds of expansion onto worksheets for the manual computing group. Then, using the algebraic properties of the function being arranged, the committee would find a method of computing values between the starting values (Grier, 1997). The Planning Committee would then break the computations into smaller units that would only use addition (group 1), subtraction (group 2), multiplication (group 3), and long division (group 4), with the computing unit only performing one of these operations. The first volume table of the exponential function to 15 decimal places was published in 1939.

The project's computation of the values of exponential functions was used to give the values to the correct rounding last decimal. The first computation was based on the value of $e\ x$ and $e^{-}x$ for a number of key arguments. These are the values of the exponentials for key arguments with the equations:

$$x = 0.0001 \text{ to } 0.0009 \text{ at intervals of } 0.0001$$

$$x = 0.001 \text{ to } 0.009 \text{ at intervals of } 0.001$$

$$x = 0.01 \text{ to } 0.09 \text{ at intervals of } 0.01.$$

These values were computed by direct substitution in the exponential series expansions recomputed by the Project after being first computed by Van Orstrand (Roegel, 2017). The values of the exponentials for $x = 0.01$ to 0.99 and $x = 0.0001$ to 0.0099 were computed to 25 decimal places by multiplying each $e\ x$ by $e^{0.01}$ and by $e^{-0.01}$, obtaining $e\ x+^{0.01}$ and $e\ x^{-0.01}$. With these values, the process can be repeated to get the values of $e^{0.02}$, $e^{0.03}$, etc, checking the earlier values.

The human computers would test the accuracy of these values using three different tests. The first, the curvature test, involved taking derivatives of a function with the values of the exponentials and testing the results with various ranges and values of h. The computed values were tested using this equation:

$$R = e^{x+h} + e^{x-h} - 2e^{x} - 10^{-8}e^{x} - \frac{10^{-16}e^{x}}{12}$$

The curvature test tested every even argument once and every odd argument twice. A geometric test was used to compare the sums with their pre-computed values. This involved summing entries in groups and comparing the sums with precomputed values. Finally, a fourth difference test was applied. Expanding the Taylor series first, then expanding h^{4}, then expanding $(1+\frac{h}{2})^4$ with $o(h)$ being other terms of higher order:

$$S = e^{x}(e^{h}-1)^4 = e^{x}(h+\frac{h^2}{2}+\ldots)^4 = h^4e^{x}(1+\frac{h}{2}+\ldots)^4 \approx h^4e^{x}(1+2h+o(h))$$

The fourth difference test checked that $S - h^{4}e\ x$ was not greater than $2h^{5}e\ x$. This test involved testing values of consecutive groups of five entries. These tests ensured that the volume was free from errors (Roegel, 2017). The computations and tests were performed by human computers and checked by Blanch herself.

During the next eight years, the Mathematical Tables Project would complete a range of tables. These included the "Table of First Ten Powers of the Integers from 1 to 1000" (1939), "Tables of Exponential Function" (1939), "Table of Natural Logarithms" (1941) (4 volumes), and "Miscellaneous Physical Tables" (1941). The project gained recognition and skill and started to do computations for specific projects. The Mathematical Tables Project was also in great demand during World War II. The Army was in need of map grid calculations and the Navy needed navigation tables for the new LORAN radio navigation system. Blanch was the government's chief consultant on computation during the war, and was also working with introductory work on electronic computers. The years following the war were a struggle for women in mathematics. The government rushed to rebuild the economy and find jobs for returning veterans, neglecting women's contributions while the men were away at war. Some senior women were able to retain their jobs at the Mathematical Tables Project, but none were given a position of authority (Grier, 1997).

In the 1950s, Blanch took a position as director for computing at the Institute for Numerical Analysis. However, Blanch faced challenges due to the politics of the Cold War and the removal of alleged communists from government positions. Blanch was not married, did not have any children, and her sister was a Communist, which caused her to be denied security clearance. This was a red flag to the Department of Commerce, who feared Communists infiltrating high government circles and targeted the Institute. The National Bureau reviewed the works of the Institute for Numerical Analysis, recommending its closure. In 1954, Blanch decided to take a position as a senior mathematician for the Air Force, where she worked on numerical methods to handle problems of turbulence, airflow, and transonic and supersonic flight. During her time at the Air Force, Blanch published about half of her 30 papers and became an early member of the Association of Computing Machinery (Formal, 2021). Some of Blanch's papers were "Table of Modified Bernoulli Polynomials" (1950), "On the Numerical Solution of Equations Involving Differential Operatots with Constant Coefficients" (1952), and "Subsonic Oscillatory Aerodynamic Coefficients Computed by the Method of Reissner and Haskind" (1953). Blanch worked on finding ways to compensate for mathematical deficiencies in computers designed for industry. Before retiring, the Air Force recognized Blanch for her contributions with awards and promotions. In 1963, the American Association for the Advancement of Science elected her a fellow and she received the Air Force Exceptional Service Award. In 1964, Blanch received the Federal Woman's Award from President Lyndon Johnson.

Blanch's work with numerical analysis for the early computers was used in an abundance of different companies and government jobs. She paved the way for women in mathematics and science and her contributions to the Mathematical Tables Project serve as a testament to the importance of the advancement of technology and the first electrical computers. Gertrude Blanch's work deserves more acknowledgment, inspiring future generations of mathematicians and computer scientists.

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