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ORIGINAL RESEARCH PROJECTS

ORYGINALNE ARTYKUŁY BADAWCZE

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Polish Women Mathematicians: A Narrative Study of Women's Career Paths in Academia

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Abstract
The aim of this article is to identify the factors that determine the development of the mathematical careers of the surveyed women. The analysis is based on the narratives of 14 outstanding female mathematicians who shared their professional and educational experiences. The study was qualitative in nature and was based on the semi-structured interview method. The selection of participants was purposeful, focused on women with recognised scientific achievements. Ten of them pursue scientific careers in Poland and four in the United States. The analysis takes into account both institutional and socio-cultural factors influencing the formation of professional trajectories. The results of the study show that despite formal equal opportunities, women still encounter structural and cultural barriers in the exact sciences. Their individual development strategies, support from their environment, and institutional involvement turn out to be crucial for overcoming limitations and achieving scientific success.

Keywords: women in STEM, mathematics education, overcoming barriers, gender gaps.

Introduction

One of the most deeply rooted myths about mathematics is the belief that its abstract nature poses a particular challenge for women in terms of understanding and practising it. In this article, the author shows how outstanding women are breaking down established stereotypes, redefining the role of science, and inspiring young girls to explore this fascinating field. Their stories not only reveal the difficulties of overcoming social and cultural barriers, but also show how changing attitudes towards mathematics education can contribute to building a more equitable and creative world. The aim of this article is to identify the factors determining the career development of the female mathematicians surveyed. Although a lot has changed over the years, there is still room for improvement in this area. The author hopes that the results of this study will not only contribute to a better understanding of this issue, but will also be used to support greater diversity and equality in science.

The liberal feminist perspective in research on women's academic careers

Liberal feminism is a branch of feminism that focuses on achieving gender equality through reforms in existing institutions and social structures. It is based on the principles of freedom, equality and individual rights, which are key values of liberalism. Liberal feminism argues that women and men should have equal rights and opportunities in every aspect of life, including education, work, politics, family, and civil rights (Tong, 2002; Wollstonecraft, 1792). Key assumptions of liberal feminism:

a) Legal and political equality – liberal feminism seeks to abolish formal legal barriers and discrimination against women, such as limited access to education, the labour market and politics. The key objective is to promote equality before the law, e.g. in electoral law or labour law (Okin, 1989; Mill & Taylor, 1869).
b) Education and self-development – emphasises the role of education in enabling women to achieve economic and social independence, while combating gender stereotypes that limit women in their choice of life path (Nussbaum, 1997; Wollstonecraft, 1792).

c) Systemic reforms – the belief that change towards gender equality can be achieved through gradual reforms within existing social, legal, and political systems (Pateman, 1988; Fraser, 1997).
d) Economic equality – the fight for equal access to employment, equal pay for equal work, and promotion (Young, 1990; Folbre, 1994).
e) Individualism – women are treated as autonomous individuals who have the right to make decisions about their lives regardless of their gender (Mill, 1859; Rawls, 1971).

In analysing the professional role of Polish female mathematicians, I refer to the perspective of liberal feminism, which, as Tong (2002) points out, focuses on guaranteeing women equal access to education, professional work, and social recognition. From this perspective, an analysis of the fate of women in mathematics reveals how, despite the formal removal of barriers**,** invisible mechanisms of exclusion or marginalisation continued to influence their career opportunities. Attention is drawn not only to the right to education, but also to the need for equal treatment in practice, e.g. in academic promotion, citations or access to prestigious research projects.

Socio-cultural and structural determinants of Polish women's careers in exact sciences, including mathematics

Women in Poland play an important role in the development of science, including mathematics, but they are still underrepresented at higher levels of scientific careers. According to a report by the Information Processing Centre (OPI PIB, 2024), women account for:

- 45% of all research and development personnel in Poland;
- 33% of research staff in STEM fields (science, technology, engineering, and mathematics) (PIB Information Processing Centre, 2024).

Data from the RAD-on system (2024) indicate that women in science are more likely to hold junior research positions, while their share of professorial positions is only 27% (RAD-on, 2024). Based on the report "When science is a woman" (Gajewska et al., 2021) and data from individual universities, women constitute between 30% and 40% of academic staff in mathematics departments (Gajewska et al., 2021), with the highest percentage of women in assistant and assistant professor positions (50–60%); at the professorial level,

their share drops to below 20%. An example from the University of Gdańsk (2020): assistants: 58% women; assistant professors: 63% women; university professors: 47% women; full professors: 14% women (Gajewska et al., 2021).

The results of Chomczyńska-Rubacha's analysis indicate that socio-cultural conditions have a key impact on women's scientific careers (Chomczyńska-Rubacha, 2006). Traditional gender roles still exist in Polish society, with women primarily responsible for domestic duties and caring for the family. Such expectations limit the possibility of full engagement in academic life and professional development. At the same time, women in science face a lack of sufficient institutional support and pressure to prove their competence in male-dominated environments.

International studies also confirm that cultural stereotypes and social expectations contribute to the underrepresentation of women in STEM. Bian, Leslie and Cimpian (2017) demonstrated that even six-year-old children associate high intelligence more with men than with women, which may influence girls' educational choices. A report by the World Economic Forum (2023) emphasises that women account for only 28% of the global workforce in STEM, and obstacles such as work-life imbalance and limited access to leadership roles hinder their advancement.

As shown by research conducted by Siemińska (2007) and Czerniak-Swędzioł & Kumor-Jezierska (2022), a number of barriers hindering women's career development in mathematics and science continue to be identified. These include:

- Self-fulfilling prophecy[1] – social expectations of women influence their actual career decisions and self-esteem;
- Sticky floor[2] – limited promotion of women at lower levels of academic careers;
- Glass ceiling[3] – an invisible barrier preventing women from accessing top positions despite their competence;

[1] The theory formulated by Robert K. Merton refers to a situation in which a false belief becomes true as a result of its influence on human behaviour.

[2] A term describing the phenomenon of women being stuck in the lowest positions at work, even if there are no formal barriers to promotion.

[3] A popular metaphor for structural barriers and invisible prejudices that prevent women from reaching higher positions.

- The queen bee syndrome[4] – a phenomenon in which women in high positions distance themselves from other women and do not support their development;
- Matilda Effect[5] – underestimating women's scientific achievements and attributing them to men;
- Implicit bias[6] – unconscious biases affecting competence assessment, recruitment and promotion.

Polish studies, such as the analysis of the RAD-on system (2024) and the report "When science is a woman" (Gajewska et al., 2021), point to clear gender gaps in academic achievements and promotions. Women constitute the majority at the doctoral level, but their share decreases dramatically at the habilitation and professorship levels (RAD-on, 2024). In mathematical sciences, women are less likely to obtain research grants and publish fewer papers in prestigious journals than men (Gajewska et al., 2021). The gender gap is also visible in access to management and decision-making positions. Reports such as "Girls to Science!" ("Perspektywy" Educational Foundation, 2024) indicate a growing awareness of the problem and the introduction of various programmes supporting women in science[7]. Although women have achieved significant success in mathematics and science in Poland, there is still a significant gap at the higher levels of academic careers. The percentage data indicates the need for further support and equality initiatives to enable women to fully realise their scientific potential.

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[4] It describes a mechanism whereby women who have achieved success in a male-dominated environment do not support younger women.

[5] A phenomenon described by Margaret W. Rossiter – the noticeable omission or marginalisation of women's contributions to science in favour of their male colleagues.

[6] A concept from social psychology referring to unconscious beliefs and attitudes that influence recruitment decisions and competence assessments.

[7] Programmes such as: mentoring – IT for SHE (Perspektywy Foundation), DareIT, Open Mentoring Programme Vital Voices Poland, campaigns promoting patterns of female careers in STEM – Girls to technical universities! ("Perspektywy" Educational Foundation, 2023), Girls to Science!, Lean in STEM, Implementation of Gender Equality Plans at universities – University of Warsaw (2021), AGH University of Kraków (2024), Łódź University of Technology (2024).

Research process, method, research tools, sample selection

The research was conducted from December 2023 to October 2024. Fourteen outstanding female mathematicians of Polish origin were included in the research. Four of them currently live and work in the United States, while the rest live and work in Poland. At the time of the study, three of the interviewees held the title of full professor, five held the title of habilitated doctor, and six held the title of doctor (PhD). The sample selection method was deliberate. The author used the snowball method[8]. All women share the fact that they have achieved above-average results in mathematics (numerous awards, prestigious internships, publications). The main research method was a semi-structured interview conducted online via Zoom/Teams. This made it possible, among other things, to talk to female mathematicians who live in the United States. The meetings were recorded on digital media. The interviews were transcribed. Each interview lasted from half an hour to two hours.

In accordance with the applicable rules of scientific research ethics and the Personal Data Protection Act, the identities of participants have been anonymised[9]. The author is obliged to maintain confidentiality and not to disclose the names of the persons surveyed without their consent. It is worth noting that none of the female mathematicians wanted their names to be disclosed. Therefore, at the end of each quotation, the interlocutors are marked with the letter 'N' (narrator) followed by a sequential number assigned to them.

Aim of the study, research questions

An inductive research strategy was chosen, which is a way of arriving at new scientific claims and testing them. It consists in generalising empirical facts

[8] "It involves the researcher starting with a small group of people who meet specific criteria, and then the participants nominate further candidates to take part in the study. This method allows us to reach hard-to-reach academic environments and ensures greater trust between participants and the researcher." See Konecki, K. T. (2000). *Studia z metodologii badań jakościowych. Teoria ugruntowana* (Warsaw: PWN Scientific Publishers), p. 185.

[9] The obligation to maintain confidentiality and not disclose names stems from data protection regulations. In Poland, the key legal act in this area is the Act of 10 May 2018 on the protection of personal data (Journal of Laws, 2018, item 1000).

according to the principle of "observe and generalise the results of observation – first observation, then theory" (Such, 1969, p. 140). The aim of the study is to identify the factors determining the career development of the female mathematicians surveyed. The main research question is:

How do the female mathematicians describe their educational and professional paths in the context of environmental conditions and social roles?

The furher questions were:

1. How important were family, teachers and mentors in developing your passion for mathematics?
2. What challenges have women faced in a male-dominated mathematical environment?
3. How women in mathematics describe maintaining a balance between their careers and family life?
4. How do women associated with mathematics imagine the future development of teaching in this field?

Method

A semi-structured interview has a script in the form of questions, but allows for the questions to be asked in any order and for additional questions to be asked to expand on the respondent's answers (Kvale, 2011). In the case of the female mathematicians surveyed, the script consisted of one main opening question and six follow-up questions. The researcher acted as an active listener, asking probing questions that developed important themes (Flick, 2012). The data analysis was conducted in accordance with the thematic analysis procedure, which, as described by Urbaniak-Zając and Kos (2013), involves identifying and organising key themes in the narrative material. This process included: reading the transcripts, coding meaningful units, creating thematic categories, and interpreting them in the context of liberal feminism. In accordance with the authors' approach, particular emphasis was placed on reconstructing the subjective meanings and narrative patterns present in the statements of the women surveyed.

Research results

The family as the foundation for developing a passion for mathematics

The female mathematicians surveyed unanimously emphasised the key role of the family in shaping their interest in mathematics. From early childhood, mathematics has been present in their lives as fun, an intellectual challenge and part of everyday life, rather than just a school obligation. "Mathematics was treated as fun in our home. No one said it was difficult, so I was never afraid of it" (N:3). My parents and grandparents often introduced elements of mathematics in a natural and supportive way, for example through playing chess or talking: "My grandfather taught me to count using chess as an example" (N:5), "My mum always said that the mind has no gender…" (N:3). Some of the respondents also emphasised the importance of healthy competition with siblings: "My older brother encouraged me to compete with him in solving equations" (N:2); "My siblings treated maths like a sport" (N:1). Others saw mathematics in the world around them – in nature, architecture, music: "I spent my childhood solving puzzles and observing patterns in nature" (N:3). These relationships are consistent with Bloom's findings (1985), who emphasises the role of the home environment and early experiences in the development of aptitudes. Gruszczyk-Kolczyńska (2012, 2015) indicate that the development of mathematical thinking in children is supported by inspiring stimuli, an open attitude on the part of adults and everyday problem situations. The experiences of the respondents confirm that it was precisely these conditions that laid the foundation for their future success.

Key support from teachers and mentors

In addition to their families, teachers and mentors played an important role in developing the mathematical interests of the women surveyed. Already in primary school, some teachers recognised the potential of their female students and supported their development: "I had an amazing maths teacher who gave me extra tasks after class and stimulated my curiosity" (N:9). Another respondent recalls: "If it hadn't been for my high school teacher, who devoted extra time to me, I would probably never have dared to apply

to study mathematics" (N:8). During their studies, mentors – often lecturers – played an important role, not only supporting academic development but also counteracting gender-related barriers. "At university, I had a lecturer who treated everyone equally – thanks to him, I felt that my skills were more important than my gender" (N:6). "If it weren't for my professor at university who saw my potential, I would never have had the courage to write a research paper" (N:7). When entering the academic environment, mentors supported women not only substantively, but also psychologically – they encouraged them to publish, participate in projects, and built their self-confidence. As Margolis and Fisher (2002) point out, personal relationships with teachers play a key role in retaining women in science. Boaler (2016) adds that positive support develops self-confidence, which helps overcome cultural and psychological barriers. For many participants, teachers and mentors served as a bridge between their childhood fascination with mathematics and their conscious choice of a scientific career, counteracting negative social messages that limit women's aspirations.

Challenges faced by women in a male-dominated environment

Although mathematics is considered a field based on logic and objectivity, many of the women surveyed pointed to the presence of gender bias in the scientific community. Most participants experienced stereotypes, questioning of their competence and unequal treatment, both in education and in their academic careers. Only one of the female mathematicians stated that she had never encountered discrimination, which, as she pointed out, could be due to different working standards in the United States compared to Poland. The belief that mathematics is "not a female field" has been repeated many times. Such opinions were expressed by both teachers and peers: "I often heard that women rarely choose mathematics because it is not 'their field'. It always annoyed me" (N:13). In another case, the lecturer's comment was both condescending and motivating: "During the exam, I heard the professor say: 'Not bad for a woman'. I was shocked, but contrary to appearances, it motivated me to continue working" (N:11). The respondents' statements indicate that women often had to work harder to prove their competence. "At the beginning of my career, I had to prove my competence twice as much, be-

cause people were sceptical about a female mathematician rather than a male mathematician" (N:11). There were also situations in which they were assigned stereotypical roles: "At a conference, I was asked if I could make coffee. Of course, it was the men who asked" (N:13). Such experiences are not isolated. As Titkow, Duch-Krzystoszek and Budrowska (2004) observe, women in Polish science often function "on the borderline of visibility" – their achievements are often overlooked and their presence questioned. Knapińska (2022) adds that the male model of academic career does not take into account the conditions faced by women, especially those combining scientific development with family life. These phenomena are also confirmed by international analyses. Blickenstaff (2005), analysing the reasons for the low representation of women in science, points out that formal equality is not enough – institutional norms and work culture must change. The "leaky pipeline" model, describing the gradual "leakage" of women from the scientific system at successive stages of their careers, accurately reflects the mechanisms observed in the Polish context.

Balance between career and family life

For many of the women surveyed, pursuing a career in mathematics meant balancing academic work with family responsibilities. Although their passion for mathematics was clear, participants often pointed to difficult decisions regarding motherhood, time management, and academic development opportunities. "The maternity break meant that I had to catch up on a lot of research work, but at the same time I became more disciplined" (N:12). Another female mathematician emphasised the importance of support from her partner: "Combining a career and family was not easy, but my partner's support and flexibility helped me to continue my research work" (N:13). Contrary to the belief that mathematics is a field detached from real life, the study showed that family life – especially in the early years of parenthood – had a significant impact on their scientific activity. At the same time, these experiences were a source of strength and discipline: "Children taught me time management better than any training course" (N:9). These phenomena are confirmed in scientific literature. Titkow (2007) describes the functioning of women in the "overloaded role" model, where professional success

does not exempt them from domestic duties. Duch-Krzystoszek (2001) emphasises that academic institutions are not gender neutral – their structure and work rhythm have been shaped to suit male careers, which makes the situation of women who are mothers more difficult. As Knapińska (2022) points out, women often function within the framework of "invisible compromises" – giving up mobility or promotion in the name of stability and presence with their families. At the structural level, many women also experience the phenomenon known as the "motherhood penalty," described, among others, by Correll, Benard and Paik (2007). Research shows that mothers are perceived as less committed and less competent professionally than women without children, which translates into fewer job opportunities, lower pay and limited opportunities for promotion. In academia, this manifests itself, among other things, in gaps in publication output, lower mobility and less participation in prestigious projects (Cech & Blair-Loy, 2019).

The future of mathematics education

The educational experiences of the female mathematicians surveyed influenced not only their career choices, but also their views on the future of teaching mathematics. Many of them saw the need to move away from formulaic teaching in favour of developing logical thinking and searching for meaning: "School should teach thinking, not just formulas. Maths is more than just memorising rules" (N:14). "I see enormous potential in an interdisciplinary approach to mathematics – it's the future of teaching" (N:12). Respondents pointed out that traditional teaching methods can be discouraging, especially for girls. They emphasised that teachers – often unconsciously – can reinforce gender stereotypes: "Since I was a child, I have been told that boys are better at maths. It was only later that I realised how much such beliefs can influence girls' educational choices" (N:5). These findings are consistent with the research of Boaler (2016) and Blickenstaff (2005), who indicate that the transmission of prejudices about mathematical ability can lower girls' self-esteem and lead to so-called learned mathematical helplessness. Gruszczyk-Kolczyńska (2015; 2016) points to the need to adapt teaching to the developmental level of students and to root it in everyday life.

Striving for aesthetics in solving mathematical problems

Virtually all women surveyed when asked what motivates them to pursue academic work emphasised that in mathematics, it is not only the correctness of solutions that is important, but also their elegance and aesthetics. For some of them, the beauty of proof was an important element of professional satisfaction: "For me, the elegance of proof is not only its correctness, but also the beauty that comes from simplicity" (N:7). "Mathematics is an art – an aesthetic solution gives me as much pleasure as solving a difficult problem" (N:14). Aesthetics was perceived not as an addition, but as an integral part of the relationship with mathematics – a source of meaning, motivation and joy in work. For some participants, mathematics became a creative and personal space. As Makiewicz (2016) notes, the aesthetics of mathematics can be understood both visually (symmetry, graphs) and intellectually – as clarity and elegance of reasoning. The solution does not have to be just correct – it can also be "beautiful" in terms of structure. Jevtić et al. (2024) indicate that perceiving beauty in mathematics can support student engagement, especially among gifted students. The respondents' statements show that the aesthetic dimension of mathematics has a real impact on the way they think, their willingness and motivation to work, and their personal satisfaction.

Conclusions

An analysis of the narratives of Polish female mathematicians reveals a complex set of factors conducive to the development of their careers in a field traditionally perceived as male-dominated. The most important supporting factors included: early family experiences free from fear and stereotypes, the presence of supportive teachers and mentors, personal commitment, and a sense of the aesthetic value of mathematics. At the same time, these women often had to face cultural barriers, prejudice and the need to balance their professional and private lives. The conclusions drawn from the study fit perfectly with the principles of liberal feminism. According to this trend, women should have equal access to education, employment and promotion, and social institutions should guarantee them conditions for equal development. Although the biographies analysed show progress and formal

equality of opportunity, the educational and academic reality still requires change – not so much in terms of structure as in the culture of functioning. There is a need for sensitivity to subtle mechanisms of exclusion (Titkow, 2007; Duch-Krzystoszek, 2001), greater attention to the messages conveyed to female students (Gunderson et al., 2012) and a departure from pedagogy that reproduces the belief that mathematics is "for boys." The liberal feminist perspective emphasises that change must take place at both the individual and institutional levels – by promoting egalitarian practices, eliminating the hidden curriculum, and supporting the mathematical development of girls and women (Tong, 2002). A new cultural narrative is also needed, in which a woman mathematician will not be an exception or a peculiarity, but one of many possible social roles.

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