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Gender Gap in Mathematics in Academic and Research Institutions: A Small Case Study

The problem of disproportionate numbers of men and women in the field of mathematics is reflected in a small number of women mathematicians in leading positions in research institutions and universities in the whole world. The studies show that the numbers of women in the field of mathematics becomes progressively lower as they climb the hierarchical ladder on academic and professional level. In our research we applied integrative approach which included collection of data from the interviews conducted with eleven women mathematicians of different age which come from Europe, North America and Australia. We were particularly interested in the strategies the participants used in order to bridge the gender gap in the field of mathematics in which they excelled. The study points to the factors that might explain their dedication to pursue the study of mathematics despite institutional and socio-cultural obstacles they had to surmount.

Key words: gender equality, gender gap, female mathematicians

Родни јаз у области математике у академским и истраживачким институцијама: студија малог обима

Проблем недовољне заступљености жена у поређењу са мушкарцима у области математике огледа се нарочито у малом броју математичарки на водећим позицијама у истраживачким институцијама и на универзитетима у целом свету. Студије показују да се учешће жена у области математике у академским и истраживачким институцијама прогресивно смањује како се пењу хијерархијском лествицом на академском и професионалном нивоу. У истраживању смо примениле интегративни приступ који је укључивао прикупљање података путем интервјуа са једанаест математичарки различитог животног доба из Европе, Северне Америке и Аустралије, као и њихову анализу. Нарочито смо биле заинтересоване да видимо које стратегије су учеснице у нашем истраживању примениле како би превазишле родну неравноправност у пољу математике. Наша студија указује на факторе који могу да објасне решеност учесница да се баве математиком упркос институционалним и друштвено-културним препрекама са којима су се суочавале.

Кључне речи: родна равноправност, родни јаз, математичарке

1. Introduction

In our article we will present an interpretation of the data collected through the interviews we conducted during 2010s with eleven women mathematicians who work as professors at universities and research institutions and who have various cultural, socioeconomic and geographic backgrounds. We focused on researching whether and to what extent the following factors contributed to their success in the academic field of mathematics: familial environment in early childhood and adolescence, educational (classroom) environment and presence/lack of direct or indirect encouragement, strategies for balancing professional development and academic duties and private life, managing family obligations and biological child bearing and gendered child rearing roles within a family as well as restrictions, obstacles and encouragement in employment setting and satisfaction with the occupational choice.

By summarizing the common experiences, personal and professional strategies devised to overcome the obstacles at various stages of education of the interviewed women mathematicians, their observations and recommendations, we aim to address the problem of gender imbalance in mathematical science. The research findings and conclusions presented in this paper are an attempt to contribute to the ongoing debate in the western world about viable interventions and policies which would efficiently address the reported imbalance. As Halpern et al. suggest: “Even when we conclude that there are meaningful differences between males and females, this conclusion leaves open the possibility that the performance gap could be narrowed or closed with appropriate instruction, just as it could be widened” (Halpern et al. 2007, 4).

2. Gender imbalance in mathematical and natural sciences: a brief overview of the past five decades of research

Numerous studies have examined various biological and sociocultural factors in order to understand and explain the disparity between the women’s and men’s engagement in mathematical and natural sciences. Intersectionality of the topic warrants research spanning many disciplines (Ceci, Williams & Barnett 2009; Blackburn 2017). In their attempt to resolve the debate on the reasons for women’s underrepresentation as professionals in STEM (Science, Technology, Engineering and Mathematics), Ceci, Williams & Barnett analyzed “all qualitative and quantitative evidence from the disciplines of psychology, education, sociology, anthropology, neuroscience, endocrinology, and economics" (Ceci, Williams & Barnett 2009, 219). More recently, Blackburn reports that her review of 1039 articles and dissertations on the topic of women in STEM higher education published between 2007–2017, "necessitated article selection from concentrations such as psychology, gender studies, cultural studies, education, [and STEM]" (Blackburn 2017, 237). Even though there are important differences across STEM fields (Ceci et al. 2014), our review of literature has shown that majority of explanations for underrepresentation of women in STEM are generally applicable to the field of mathematics.

Until the 21st century, "[e]xplanations of the gender imbalance in participation in mathematics [were] usually split into two categories—biological and sociological—with these being seen as directly opposed" (Mendick 2005, 237). Biological factors are believed to differently affect men's and women's cognitive skills and mathematical abilities which, in turn, influence women's (under)representation in STEM. According to Ceci, Williams & Barnett, the biological explanations can be grouped and summarized as follows: differences in brain structure (structure, organization); evolutionary pressures; and the effect of prenatal sex hormones on the brain as well as postnatal activating hormonal effects such as puberty, menstruation, contraceptives or menopause. Theories considering solely biological factors have been criticized for biological determinism or gender essentialism (Ceci, Williams & Barnett 2009). Schoon explains that "assuming that men for example have a higher aptitude in maths or spatial ability than women because of innate, biological factors implies that these differences are fixed and cannot be changed, and that the scarcity of women pursuing maths-related careers is an inevitable fact" (Schoon 2015, 154). Essentialism, thus, perceives as futile efforts to change the state of things.

Socio-cultural perspective focuses on social, political, cultural and economic factors when exploring reasons behind women's lower participation in mathematical science. Some of the socio-culturally based explanations for this imbalance include: performance in mathematics is correlated with feelings of enjoyment, confidence, or anxiety towards mathematics (Fennema & Sherman 1977); mathematics is stereotyped as a male domain (Schildkamp-Kündiger 1982, 4); important socializers (teachers, peers, parents) reinforce stereotypes that women do not do well in mathematics (Fennema 1977); stereotype-threat affects the performance in mathematics, but female role models protect women's math test performance from the adverse effects of the gender stereotype (Marx & Roman 2002); childrearing adversely affects women's careers in all fields, but it might be apparent in math-intensive fields where their number is already low (Ceci et al. 2014). Blackburn's review reveals that topics like "[s]tereotypes, biases, [chilly] campus culture, classroom experiences, identity and sense of belonging were also reflected in the literature" (Blackburn 2017, 237). In their extensive overview of the scientific research of sex difference in mathematics, Halpern et al. conclude that "[s]ociocultural forces also influence sex differences in math and science abilities, academic-course choices, occupational success in math and science careers" (Halpern et al. 2007, 41).

2.1 Toward reconciliation of nature and nurture in 21st century

The first two decades of the 21st century saw emergence of reconciliatory and integrative approaches in studying and explaining the gender difference in mathematics thus combining the arguments and research findings from the two perspectives which were previously colliding. Basically, the main starting hypothesis of such integrative research on the topic is that human behavior and capabilities adapt to the context in which they exist and develop. Therefore, it is safe to conclude that neither biological nor sociocultural approaches alone can fully and comprehensively explain human behavior. An overview of the research and studies of gender differences in mathematics across racial and ethnic groups up to 2007, shows that no single theory such as "[m]otivation, learning, biology, or test-related anxiety can satisfactorily explain the difference in recorded cognitive abilities and, more importantly, career achievement. The reported and recorded sex differences in mathematical achievement are a result of a remarkably complex combination of native ability, socioeconomic context, personal interests and cultural influences" (Halpern et al. 2007, 30-31). It is important to point out that the full corpus of data and research findings do not warrant reducing causes of gender imbalance in STEM to a single culprit (Ceci et al. 2014). Also, focusing on a single factor or process is not sufficient to explain "the interlinked and dynamic nature of human development that is embedded in a changing socio-historical context" (Schoon 2015, 152). In other words, only an up-to-date integrative theory which would account for biological traits (e.g. child bearing) and situate them in a dynamic social context could satisfactorily explain the reported gap and devise effective recommendations to minimize it.

The research exposes the gender gap as pervasive and persisting, but also narrowing due to interventions. "Evidence is strong that gender disparities in STEM encompass gaps in representation, compensation, research awards, and, to a lesser extent, grant success and authorship" (Charlesworth & Banaji 2019, 7233). This is particularly important as in the 21st century we see a shift in the representation of women scientists in natural sciences at the universities and research institutions. As data gathered by European Women in Mathematics show, the percentage of women mathematicians rose in the period from 1993 to 2005 by 5 to 10% in the countries in EU. However, the percentage of women full professors in mathematics in the same countries rose by only 1 to 5%. The exceptions are Portugal with 26% rise and Estonia with 10% rise. One should have in mind though that Estonia in 1993 had 0.0% women full professors in mathematics while it did have 29,4% women mathematicians (European Women in Mathematics 2018). Similarly, research conducted by Solomon, Radovic & Black shows that "in UK Higher Education, female representation also drops in the move from undergraduate to postgraduate studies (in mathematics from 43% to 35%), with only 6% of professors in mathematics in the UK being female (London Mathematical Society 2013). In the mathematically demanding general area of STEM, only 13% of all STEM jobs in the UK are occupied by women" (Solomon, Radovic & Black 2015, 1). Likewise, Dragana Popović concludes that relatively high number of women graduate from natural sciences in Serbia, but the number of those pursuing professional academic career declines either because women find themselves in conflict with their traditional roles as wives and mothers or because they opt to teach physics in primary and secondary schools (Popović 2005, 125). Moreover, even though women have made uneven, but steady gains in entering STEM courses at university and being represented in STEM occupations, they are less likely than men to hold university administrative positions such as deans, directors or department chairs (Ceci et al. 2014).

3. Our interviews with women mathematicians

Despite similarities outnumbering the differences in mental traits and mathematical abilities (Hyde 2014), "the outcomes and experiences of men and women in STEM continue to exhibit difference" (Charlesworth & Banaji 2019, 7240). We pondered why such gender inequity in the academic field of mathematics and science persists at universities and research institutions. Despite differences in the stage of academic advancement, age and exposure to different educational environments, the three of us encountered strikingly similar obstacles and dilemmas in our professional and private lives. The initiative for our research came from Slobodanka Markov who at the time worked at the School of Science in Novi Sad and noticed gender imbalance between men and women in the field of natural sciences.[1] Coming from humanities and social sciences (sociology, English studies, and gender studies), we started conceptualizing research on women in STEM. The conference of European Women in Mathematics held in Novi Sad provided a great opportunity to document and analyze experiences of women scientists in the field of mathematics. Thus, to explore some of the reasons for the recorded gender inequity, we conducted interviews with eleven women mathematicians from different cultural, socioeconomic and geographic backgrounds, who have different personal histories and were educated in different educational systems. We will not further analyze the differences among the educational systems as our data presented in the article show that interviewed female mathematicians encountered similar problems in their careers regardless of the educational system in the country of their origin. What proved to be the most dominant factor splitting our sample is generational difference which we will discuss later in the article.

In contrast to large scale studies which rely on statistical analysis of quantitative data, our small case study is part of a more contemporary trend of collecting reports of lived experiences to better understand real-world conditions. Blackburn notes that recent research relies on collecting and analyzing the reports as a holistic lived experiences, "[a]side from comparing test scores, graduation rates, and career placement" (Blackburn 2017, 251). To examine and address the persisting gender inequalities in STEM, Schoon calls for an integrated effort in understanding the interplay between individual agency and social structures and "multiple causes of influence that occur over the life course" (Schoon 2015, 152). Documenting and contextualizing the lived experiences can reveal timing, nature and confluence of motivating factors and encountered obstacles, which may elude quantitative data anal-

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[1] For more on this see Markov, 2006.

yses or experimental research. Additionally, self-reported data can inform better responses to “multiple interlinked inequalities that occur at different stages of the life course” (Schoon 2015, 152), when validated by and combined with different type of evidence. The size of our sample poses a limitation to generalizing conclusions, but this exploratory research aims at identifying major issues. We hope it will prompt and direct further in depth-research on a larger sample and, where applicable, include all genders. Ultimately, the data gathered from our interviews may help unearth useful recommendations and tools for future interventions devised to remedy the occupational imbalance in mathematics and science.

We assume that each interviewed woman possesses relevant cognitive abilities necessary for mathematical research at academic level. Assessment of mathematical abilities, skills and knowledge of the interviewees is certainly beyond the scope of this paper and presumably has already been assessed through other institutional means. We decided that the academic achievement and recognition are not the most objective but are sufficient evidence that the interviewed women possess cognitive abilities necessary for advanced mathematical reasoning. We also assume that these abilities are at the level of their male colleagues.

We are also fully aware that academic advancement requires development and use of a plethora of other skills and abilities, such as social and networking skills or abilities to navigate through and function in bureaucratic structure of a university or other institution. All women we interviewed testified to the importance in their perseverances to study mathematics despite the institutional and sociocultural obstacles they encountered. They advanced in academic career and gained due recognition in the reportedly men-dominated scientific field. Most importantly, the interviewees testified that passion and love for solving mathematical problems propelled them to advance despite the numerous obstacles and disappointments. This study did not extend to collecting and interpreting qualitative data from male mathematicians, so this is not a comparative study. However, having the last observations in mind, we found no reason to assume that our respondents are an exception from the general female population. They are not biological peculiarities, females who possess so called ‘male brains’ which would enable them to engage in the study of mathematical problems. Rather, they had interests, potentials, talents and aspirations which they pursued motivated by the passion for mathematics, despite the reported and documented gender-unfriendly environment during their studies and later at work.

Therefore, the aim of this research was to understand and explain to what extent social and cultural factors, combined with reported passion for mathematical problem-solving, contributed to academic advancement of the women mathematicians, we interviewed as well as to their scientific achievements and feelings of professional fulfillment. Slobodanka Markov was responsible for overall coordination of the research, drafted the questionnaire, and maintained correspondence with interviewed women mathematicians. Senka Gavranov drafted the questionnaire, conducted the in-person interviews and together with Aleksandra Izgarjan reviewed the relevant literature. All three of us analyzed the data, and formulated conclusions and recommendations presented here.

3.1 Methodology

The face-to-face interviews were conducted in August 2009. Some segments of the interviews were continued with the participants throughout 2010s. Each interview was conducted separately in a classroom or office at the Faculty of Sciences, University of Novi Sad by Senka Gavranov, a student in gender studies familiar with academic milieus in two countries (Serbia, Canada) and who is fluent in English at the level of an educated native speaker (C2). Prior to conducting the interviews, she participated in drafting the questionnaire and consulted extensive literature on the topic. The in-person interviews were semi-structured and the questions (provided at the end of this article) served as guidelines for the interviewer to ensure that the major milestones of the life trajectory and professional development are covered, while accommodating for the specifics of life and professional circumstance of each of them to be included as well. We selected semi-structured interviews because they provide comparable qualitative data, while facilitating insights into experiential and evaluative data which other field-research tools may not provide. Thus, the data obtained through the interviews and questionnaire are multi-layered, as they contain both factual data and the respondents' emotional responses. The questions about education, career choice and satisfaction with the chosen profession certainly invite responses which will be to an extent emotionally charged. The interview also contained questions which invoke value judgments or encourage evaluation of the scientific field.

In the selection of the participants in our study, we applied six criteria: active in the field (e.g. not retired), geographical background, prominence and achievements in the field in the country where they work and abroad, history of migration (for work), and good command of English language. Generational and geographical background of the eleven women mathematicians in the sample is purposefully diverse. Three interviewed women were born in the mid or late-1940s, five in the mid- and late-1950s, while three of them were born in the decade between mid-1960s to mid-1970s. Five women scientists originate from the Western European countries (Belgium, Germany, France), three are from the countries of the former Soviet Union (Lithuania, Moldova, Russia), one is from North America and Australia respectively, while one is from Serbia. Five women have lived and worked in their country of origin without ever relocating, while six of them have moved for professional reasons. One has moved within Europe, one within North America, while three have moved between Europe and North America and one across all three continents, Europe, North America and Australia. In our small sample the reported experiences of the interviewed women, indicate that their geographical background (including educational system in the country of their origin), country of citizenship and migration status, did not influence the professional and scientific development to a noticeable degree.

3.2 Research hypotheses and major findings

Our first hypothesis is that at some level of educational advancement, our respondents have experienced struggle with the opinion that women are naturally (biologically) better at social and verbal tasks, while men naturally excel in numerical and visuospatial abilities. The hypothesis proved to be correct. Majority of our respondents covertly, rather than overtly, experienced gender bias at the higher stages of their education and professional experience. Historically, mathematical science was explicitly perceived as a domain of human intellectual engagement belonging to men. It appears that the view that male brain is equipped with capabilities necessary for mathematical and abstract reasoning was translated into social field where it remained tacit. This in turn may have contributed to creating obstacles for women to enter and advance in the field of mathematics at the systemic level. More specifically, our starting point was an assumption that the respondents might have experienced isolation in their workplaces and difficulties integrating into their work communities because mathematics appears to be a gender-segregated profession. Older generations of the interviewed women reported this occupational characteristic and structural features of their employment setting, while for the younger ones it was less prominent.

Secondly, and based on the relevant literature, we hypothesized that encouragement and support of the primary family at an early stage of educational life can be a crucial factor in recognizing the talents and interest for mathematical reasoning and pursuing its realization. However, the data gathered from the interviews did not support this hypothesis fully. Namely, while the importance of familial encouragement proved to be of some importance, it is not a factor sine qua non. In other words, in cases where familial support was evidently absent, the interviewees still continued pursuing their interests and developing their potential.

Even though we assumed that interest in mathematics is a relevant factor for engagement in mathematical science, the extent to which it seems to have been the decisive and driving force for the interviewed women is surprisingly high. Simply, passion and love for doing mathematics and solving mathematical problems emerged as a common and most relevant factor for achieving success in the (statistically) men-dominated academic world of mathematics.

3.3 Data analysis and findings

3.3.1. *Lack of systemic support in pursuing interest in mathematics*

According to our research data combined with the findings presented in other relevant studies, it appears that the educational structures at the institutions which our respondents attended have not sufficiently developed and applied methods which would detect potential in children or adolescents or encourage further proper channeling of interests.[2] In our sample, almost all interviewed women, irre-

[2] Additional research on a larger sample and including all genders may determine the extent to which this finding is gender-specific and whether it can be generalized.

spective of age, their country of origin, and educational system they belonged to, emphasized the crucial role of individuals in their lives who encouraged them to pursue a career in mathematical sciences.

At early stages of education, passion for work with numbers and shapes appeared to be motivational to the extent it was recognized and nourished by the immediate environment. The earliest and most immediate socializers in the case of our respondents were the primary care givers. Here, however, we can notice a subtle manifestation of gender stereotypes related to mathematics. Namely, two thirds of our interviewees reported influence of their fathers who either engaged them in mathematical problem solving through play or directly articulated the encouragement. Based on the women's responses, it appears that the level of the education of their fathers is directly correlated to their support for the female child to pursue her interests. The more educated the father, the level of his involvement had seemed to increase. The findings that fathers, and not mothers, initiated games with numbers appear to link mathematics with a male figure. Still, it must be noted that in comparison to the fathers, the level of the education of the mothers of the respondents proved to be irrelevant, as they all, to different degrees and using different ways of expressing their support, encouraged and assisted their daughters to pursue their interest in mathematics.

The reported experiences of interviewed women scientists show that encouragement to pursue the interest in mathematics was not built into the educational system. It does not mean that they were autodidacts, but that the direction of their intellectual development depended on the kindness of individuals, mostly teachers. Two of them even explicitly called themselves 'lucky' to have a teacher/mentor who recognized and supported their interest in mathematics. They also regretted the unfortunate possibility that a number of talented children go unrecognized and that their skills and knowledge are unappreciated.

3.3.2 *Generational differences: lack/presence of women role-models in mathematics*

Responses provided by three age groups in our sample enabled us to compare their experiences and social and educational circumstances in diachronic perspective. On a larger scale and with a bigger sample, such comparison may expose certain socioeconomic trends in incorporating gender-specific policies into educational practices and employment environments.

In the seventies and eighties of the last century, mathematics was overtly "stereotyped as male domain" (Schildkamp-Kündiger 1982, 4). In many mathematical departments there were either none or only one woman professor of mathematics. For three of the interviewed women, entering the departments of mathematics in those times was a pioneering endeavor. Aside from struggling with stereotypical attitudes and opinion about women's intellectual capabilities, staying and pursuing the career in an unwelcoming and skeptical working environment required courage, dedication and determination.

Younger generation of mathematicians born between mid-1960s to 1970s in our sample reported that the presence of women in their departments helped them in two ways. Firstly, the environment changed, became more gender sensitive, open to women, or at least less resistant to women's entrance into the academic world of mathematics. On the other hand, having role models motivated them additionally. For example, two interviewees reported that working with a female colleague who was a scientist and a mother, helped them realize women can pursue academic careers and that it should not be viewed as something extraordinary. Having a generation of women mathematicians, who came before them, had also helped younger women gain and project confidence in their abilities and performance. Three respondents recommended incorporating female mathematician role models into programs for promotion of mathematics among young women and girls. Similarly, Marx & Roman suggest that "increasing the number of female role models in math and engineering classes may allow female students to view the negative gender stereotypes that confront them as surmountable barriers" (Marx & Roman 2002, 1192). It also may mitigate, if not eliminate, the stereotype threat effect on female math performance.

Stereotype threat is a theoretical concept which may be useful in explaining women's lack of confidence in professional matters as several interviewees noted. Reviewing the research on the topic, Halpern et al. explain that "[a] negative stereotype about one's group may lead to self-doubt and other processes that can then undermine academic performance" (Halpern et al. 2007, 33). Stereotypical image that women are not good at doing mathematics may prompt insecurities and negatively influence self-perception in women when they deal with a mathematical problem at any educational level. Two interviewees born in the 1940s recalled their initial diffidence which might be due to the lack of role models in their working environment. They observed that they became more self-confident as time went by and they gradually came to realize that they could succeed in their academic careers in mathematics. Four interviewed women from the 1940s generation recalled that up until they found themselves in a position of a researcher in mathematics, they simply did not know that such a job had existed at all. According to them, this lack of information about career opportunities throughout their early and even university educational years was a main contributing factor for their self-reported lack of clear direction and guidance in educational and academic development. At a young age, they thought that a woman pursuing her interest in mathematics can only become a math teacher in an elementary or high-school. Nothing and no one in their surroundings convinced them otherwise.

Our younger respondents, those born between mid-1960s to mid-1970s, reported that they were aware of that research careers in mathematics existence at the time they embarked on their career paths. Additionally, they had examples of women scientists and university professors of mathematics in their immediate surroundings or primary family, which testifies to the importance/beneficial influence of female scientists as role models from an early age. This is in accordance to the guidelines of The American Association of University Women study of the underrepresentation of women in STEM careers which suggests that in order to combat stereotypes, it is important to "[e]xpose girls to successful female role models in math and science. Exposing girls to successful female role models can help counter negative stereotypes because girls see that people like them can be successful and stereotype threat can be managed and overcome" (Schaffer 2017, 378). Diversification of career-advising services which many high-schools and universities have established may be one of the practices which could diminish the effects of the lack of information about the career choices available to the young women and men. Having female faculty may also signal that the discipline welcomes women and embraces diversity. Nevertheless, Karl Schaffer cautions that "a few stories about successful women mathematicians might simply be taken as lonely exceptions to the biased 'rule' that women cannot do mathematics" (Schaffer 2017, 378). Instead, including large numbers of names and photos of women of all ethnicities and ages who have become successful mathematicians serves to counter this assumption (Schaffer 2017, 378).

3.3.3 *Generational differences: employment setting and gendered familial roles*

Generational differences in our sample are noticeable, especially in relation to the employment opportunities. Noted generational difference in ways of obtaining a job is most probably gender-neutral difference as university and job market exerted much less pressure on students and (potential) employees in the pre-1990s era. Five interviewed women born in the mid or late-1940s and mid- and late-1950s, reported that getting jobs was relatively easy for them and that they felt no pressures to plan career from early stages of education as it appears to be a norm recently.

Beside this gender-neutral difference, the generational gender-specific differences within the group of respondents are relevant when it comes to experiencing forms and manifestations of gender-based discrimination. Two mathematicians born in the 1940s reported that they were either first or the only women in the departments of mathematics in the 1970s and 1980s. Women in a largely men-dominated system such as mathematical academic world encountered various overt or covert articulations of resistance and inertia. Overt display of gender stereotyping and doubt in capabilities of women scientists are exemplified in the experiences of our respondents from the 1940s and 1950s generation. For example, one was not offered a job because she was a woman and the assumption was that it should be her husband who should get a job first. She explained that both had similar educational background, but that the job was not offered to her, because it was expected that she would follow her husband. One woman scientist described that she was the first woman elected to a highest scientific board consisting of more than twenty male members. She related that during the first couple of meetings she was sent to bring refreshments, until she expressed her refusal to do so any longer. Another respondent who worked in the US especially emphasized the benefits of affirmative action measures for women since in her opinion they contributed to the diversity of her workplace and the working environment of her female colleagues.

In the 21st century, overt manifestations and examples of gender-stereotyping are quite rare in the western societies. Instead, covert forms of discrimination operate in contemporary western societies, such as forcing women to sacrifice the family life for the sake of their career. Quoting rules of the market economy, introducing measures which would increase efficiency of an employee by demanding extended working hours for example, affects all employees regardless of their gender. However, discrimination is not only manifested through overt display of unequal treatment of groups of people, in this case, women. In order to account for, anticipate or remedy consequences of gender-based injustice in socioeconomic interactions, the definition of discrimination is expanded to include its covert forms. Thus, imposing the same requirement for all genders, even though one may face difficulty to meet the requirement, is also viewed as a discriminatory practice. Blackburn summarizes that "[c]ultural stereotypes shape gender biases and influence interpersonal interactions within institutions [steering women] toward careers or away from others" (Blackburn 2017, 244). According to research, it appears that not explicit, but implicit biases embedded in the institutions and policies inform educational and occupational choices as well as women's personal decisions. For example, requirements to produce more scientific articles, to teach more classes in addition to increased administrative workload demands to work extended hours leaving little or no room to attend to family obligations. Such seemingly gender-neutral demands may be a disadvantage for women, which may influence their educational, professional and personal decisions differently than men.

Seven interviewed scientists discussed child nurturing responsibilities as a major difference between women and men employed in the academic world of mathematics. Four of them concluded that the conditions in the employment setting for professional advancement of women and men are equal, but that women have more duties outside of work. Nevertheless, all of them observed that generally, childcare appears to affect women's scientific work and careers in various ways. For example, two scientists assessed that the demand to work long hours collided with childcare efforts and needs. An interviewed woman mathematician born in the 1970s reported that her female colleagues had expressed their concerns and worries at the prospect of having children and maintaining a career of a researcher. Unless these colleagues had a partner who is committed to active parenthood, they are postponing the decision to have children. Additionally, two scientists observed that parental leave gap can have negative effect on skills and research. Our respondents also noted that a significant number of women slowed down their pursuit of academic career when they entered their late child-bearing years or gave up academic career completely, as, according to Ceci et al. "[t]ime flexibility is thus a priority for at least a portion of women who excel in science" (Ceci et al. 2014, 127). Two respondents observed that mathematically-gifted women opt for careers which allow better combining of family and professional life, such as teaching mathematics at primary and high school level, while one cautioned that trying to fulfill all duties can lead to burnout. Thus, Charlesworth & Banaji propose that "[a]llowing flexible work arrangements in STEM can have beneficial effects on the treatment and advancement of women (particularly mothers) because the arrangements both endorse and facilitate communal and family values" (Charlesworth & Banaji 2019, 7239).

Interviewed women mathematicians born in the 1940s emphasized that a more relaxed and less market-oriented employment setting was more conducive for balancing career and family life. Two interviewees from the countries of the former Soviet Union mentioned that they had long breaks from university duties, up to five years, to attend to their child nurturing needs, after which they returned and resumed the work. Aside from the advantages of more family-friendly economic system and employment setting, all nine interviewed women who have children emphasized tremendous help from the supportive husband or assistance of primary or extended family. Eight of them who lived with a partner/husband with whom they have children reported that their partner had the same share of responsibilities related to childcare as they themselves. For one, female members of the primary family (family of orientation) such as a mother or a sister provided crucial assistance and support.

4. Conclusions

Based on the interviewees' responses, love and passion for mathematics had been for them the principal impetus to excel. Throughout the interviews, the women mathematicians repeatedly emphasized that experiencing emotional fulfillment and satisfaction with intellectual engagement when solving a mathematical problem had been a major motivational force which had propelled them to engage further and deeper into at times unwelcoming world of mathematics. This experiential and emotional phenomenon, however, appears to be coupled with either familial support or a teacher's encouragement and beneficial formative influence. The experiences our respondents reported reinforce the idea that innate ability, interests and environmental support are extremely entangled and motivationally circular. As Halpern et al. assert "[i]t is difficult to know whether high ability leads to increased interest in an academic domain or whether high interest in an academic domain and engaging in activities that develop expertise in that domain lead to high ability" (Halpern et al. 2007, 3).

Literature on the topic, our research and testimonies of our interviewees show promise for increasing the numbers of women and improving their position in mathematical science. Additionally, the interviewed women mathematicians identified possible avenues for further research and interventions: the effects of different parental leave and child care policies, time-flexible work arrangements, influence of role models, programs for promotion of women in mathematics in early education, programs for teacher- and parent-sensitization to recognize and nurture talent, to name a few. We agree with them, yet as we conducted this exploratory research on a small sample, further examination and analysis of noted phenomena is needed before producing definitive recommendations. At this juncture, we certainly recommend (diachronic) country-wide surveys and especially comparative qualitative studies analyzing different educational systems, which would include all genders. Such research may also encompass assessment of the effects of implemented interventions. However, to ensure systematic support for all (talented) children and youth, the educational system and teaching practices should be regularly assessed through various screening methodologies. This assessment must include issues related to the recorded gender-imbalance and produce the recommendations for ensuring that more women interested in mathematics realize their full potential and stay in the discipline contributing to its advancement and diversification of its methods and approaches.

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Annex: Questionnaire for the Interview with Women Mathematicians

Primary family background, childhood

1. Could you please tell us something about your childhood: your family, interfamilial relations, your parents' influence on your formative childhood years? Please describe your experiences of your immediate and general socio-cultural surrounding during your childhood.

2. Please describe the development of your motivation for education and the influences of your parents and siblings, and other adults from your surroundings on this development.

Formal Education

3. Please describe the beginning of your education, your perception/experience of the authority of teachers, socialization with peers at school, generational identity.
4. When and how did you notice your interest in mathematics? What was a crucial influence or event for the development of this interest?
5. Please describe the development of aspirations in regards to the professional career. Was your interest for the specific mathematical sub discipline formed during your undergraduate studies?
6. How would you describe your relationship with colleagues and professors during your studies?
7. Did you decide to have an academic career during your studies? Who supported you in your decision?

Academic Career: Results and Achievements

8. Could you please tell us about the process of obtaining academic titles: encouragement and obstacles?
9. Have you ever experienced or noticed differences in career advancement between you/your female colleagues and your male colleagues? If yes, please describe them shortly.
10. How would you assess the presence of women in mathematical scientific disciplines at your university or in your country? From what you have observed, do they have the same conditions for professional development and advancement as your male colleagues?

Private and Professional Life: Family

11. How have you managed to balance out your professional engagement and your family life? Whose support and help was crucial in successfully harmonizing the family and professional life?
12. How did you harmonize your and your partner's or spouse's career?
13. If you compare conditions for the advancement of women in mathematics at the time when you started your professional engagement and nowadays, do you notice any differences or improvements?
14. As we are interested in the process of affirmation of women in a scientific discipline like mathematics, could you please tell us whether you felt or experi-

enced any barriers or limitations in advancement of your academic career because of your gender?

Personal Satisfaction and Fulfilment with the Choice of Career

15. Are you content with the career you chose? What inspires and motivates you to continue working and contributing in your scientific discipline?

A Message to Young Women Students of Mathematics and Future Scientists

16. Do you have a message to young women who plan to study mathematics and wish to embark on building a career in mathematics?
17. In your opinion, what would be an effective strategy to encourage women to study mathematics and decide to develop academic careers in this scientific discipline?

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