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Please, Mind the Gap. Gender and Computer Science Education

ABSTRACT. Functioning in contemporary reality requires a variety of different skills, but computer skills are among the most prevalent ones. In this article, we review theories and research related to the gender gap in computing and computer science education, as well as provide several possible lines of explanation of this gap, organized around the psychobiosocial model of gender differences. We demonstrate this gap in Poland using different data-based exemplifications, i.e., showing the gender gap among participants of national contests in programming, awardees of prestigious fellowships for young scientists or showing gender differences in scholarly positions. We discuss reasons and consequences of the identified gap in education, but also in society as a whole.

KEYWORDS: computing; computer science, gender gap, biosocial model

Almost two centuries ago, after nine months of work, Ada Lovelace (daughter of Lord Byron), created the first abstract algorithm applicable for a mechanical machine. It came to be known as *Analytical Engine* (Huskey & Huskey, 1980). Since that time, Lovelace is perceived as the first female computer programmer (Gürer, 2002). Interestingly, many still find this positivist rather than romantic story controversial and doubtful (Huskey & Huskey, 1980), which resembles social resentments related to females' creative abilities in computer programming and science in general (Ceci & Williams, 2010).

In this paper we explore the complex and still controversial issue of the relationship between gender and effectiveness of functioning in the wide area of computer science. It goes almost without saying that regardless of the astonishing achievements of women in science and business (Abbate, 2012, but see also Gromkowska-Melosik, 2014), computing is still the 'boys' clubhouse. Successes of Grace Hopper (also known as Holy Grace), Adele Goldberg, Anita Borg (Gürer, 2002), Carly Fiorina, or Meg Whitman (Yost, 2010) are far less known than those of Steve Jobs, Bill Gates or Marc Zuckerberg. Paradoxically, since the eighties we have observed a systematical falloff of women in computing (Hayes, 2010), and in 2015 girls and women are still out of the computer science loop (Margolis & Fisher, 2002, p. 2). Small and decreasing proportion of women studying and working in computer science raises a lot of concerns (Cohoon, 2011). During the last few decades, researchers, educators, entrepreneurs, and policy makers have considered and examined the possible explanations for this underrepresentation (Dryburgh, 2000; Margolis & Fisher, 2002), and the gender issue in CS has formed a separate area for scientific analysis and public debate (Lagesen, 2007; Roberts, Kassianidou & Irani, 2002). In 2009 and 2010 the National Science Foundation invested around $20m. in research projects aimed at encouraging women to join computer science and other computer-related fields.

Interest in gender-fair issues in Science, Technology, Engineering, and Mathematics (STEM) is being linked to the increasing role of computing technology in contemporary world. Steady progress and powerful potential of information technology (IT) not only develops the global economy, but also influences social interactions and alters forms of education. Personal computers, smartphones, online and mobile services have become an integral part of today's people daily and professional activities. The worldwide Measuring Information Society Report has demonstrated that in 2014 almost 3 billion people around the world used the Internet, and nine out of ten Polish households with a child were connected to World Wide Web.

High-technology development, digital innovations and access to information play crucial role in quality of life and economic growth. 20th century factories have been replaced by IT businesses and start-ups. ICT industry's revenues in Poland increased by one-third between 2009 and 2012, and so did the number of companies and employees in IT and ICT. Explosion and expansion of information technology form new citizens and workers who should "parrot less and think more" (Prensky, 2011, p. 3). As Marc Prensky (2011) argues, such "meta" skills as problem-solving, critical thinking and programming will play a crucial role in the 21-st century, especially that programmers, computer engineers, and computer science educators represent the so-called Super-Creative Core of the creative class (Florida, 2002); the main goal of their work being problem-solving and discovering new solutions. This industry usually offers not only well-paid and abundant, but reputable and creative jobs as well. Therefore the gender gaps – if observed here – should be considered especially problematic (see also Baer & Kaufman, 2008; Gralewski & Karwowski, 2013; in press or Karwowski, Lebuda, Wiśniewska & Gralewski, 2013 for a more general overview of gender differences in creativity).

Plenty of research from different countries and cultures has documented the role of gender-specific barriers behind females' underrepresentation in computing (Busch, 1995; Cheryan, Plaut, Davies & Steele, 2009; Galpin, 2002; Kodaki & Berdousis, 2015; Lagesen, 2008; Papastergiou, 2008; Shashaani, 1997; Vekiri, 2010). What we provide in this article is a data-driven line of potential explanations of the gender disparity in this field. More specifically, we discuss psychological, educational and social factors standing behind the gender gap in CS. This paper is organized around four sections: we start with a brief overview of the specificity of computer science and its links with cognitive abilities. Then, we review Polish data that reflects the magnitude of women's underrepresentation in computer science. Then, we switch to possible explanations, scaffolded by the psychobiosocial theoretical framework of gender differences (Halpern, Wai & Saw, 2005). Finally, we offer some arguments about several educational and cultural determinants that shape and enhance the gender gap in the field of computing.

1. Specificity of the Computer Science Domain and Programming Proficiency

As we have mentioned above, computing skills drive innovation required for global economic competitiveness (White, 2010). Particularly, however, computing skills may exert powerful influence on learning and functioning in the whole domain of education. In 2006, the European Parliament and Council presented a recommendation concerning eight key competences for lifelong learning. Two of them are especially relevant for our argument: (1) mathematical competence and basic competences in science and technology and (2) digital competence, both directly linked to computer science, which is perceived as a strongly math-related field. While today the basic level of computer literacy is usually considered quite an obvious and natural skill (especially for digital citizens; see Prensky, 2011), the burgeoning requirements and expectations of the modern labor market increase creative aspects of using computers and technology. Computer programming is but one example.

For the purpose of this article it is worthwhile to present a short analysis of terminological distinctions regarding the field of computer science (CS), as there are several definitions of the field itself. Association for Computing Machinery (ACM) defines computer science as "an integrated field of study that draws its foundations from mathematics, science, and engineering" (ACM, 2001). In turn, The Computing Sciences Accreditation Board describes CS as a discipline that "involves the understanding and design of computers and computational processes" (CSAB). Combination of mathematics and engineering fields forces computer scientists and IT employees to think computationally, not only mathematically. Almost ten years ago, Jeannette Wing (2006), professor of computer science at Carnegie Mellon University claimed that computer science is the study of computation and proposed the term *computational thinking* (CT) to describe another skill (or set of skills) crucial for contemporary people. Wing strikingly highlights that CS is not only about programming computers, but instead she postulates the idea of computational thinking defined as specific thought process that consists of heuristic reasoning, as well as abstractive and recursive thinking. Computational thinking is hence closely related to insight problem-solving (Bar & Stephenson, 2011) as it is engaged in such different phases, as reformulating the problem or efficiently enhancing solution discovery. Wing's conclusion is that computational thinking " (…) includes a range of mental tools that reflect the breadth of the field of computer science (…) and is a fundamental skill for everyone, not just for computer scientists. To reading, writing, and arithmetic, we should add computational thinking to every child's analytical ability" (Wing, 2006, p. 33). This may be taken even further by positing that such understanding of computational thinking is conceptually close to creative thinking as commonly defined by psychologists (Guilford, 1960; Treffinger, 1985; Torrance, 1972). Despite the complexity of computational thinking and pervasive enthusiasm toward computer science, both are too often simplified. For instance, even in CS computer programming is defined as *coding*. Because coding is *trendy*, there are plenty of such worldwide initiatives as Hour of Code, Code for Life, Made with Code, coding competitions or special coding events. However, programming is not a single coding activity; it is a process that consists of several stages: (1) understanding the problem, (2) designing, (3) coding, and (4) comprehending and debugging (Pea & Kurland, 1983). Noteworthy, the aforementioned "mental tools", i.e. procedural and conditional reasoning, planning, and analogical reasoning are likewise required for programming proficiency. What is more, a reciprocal relationship between cognitive abilities and computer programming skills has been reported, so some 'core cognitive' abilities and styles boost computational thinking and programming competence (Bishop-Clark, 1995), but training in this field proves to be effective in developing such thinking as well (Clements & Gullo, 1984).

Six cognitive factors are usually considered as crucial abilities that influence computer programming. These are: mathematical ability, memory capacity, analogical reasoning skills, conditional reasoning skills, procedural thinking skills, and temporal reasoning skills (Pea & Kurland, 1984). Moreover, the role of mental models (Mayer, 1989), spatial ability (Jones & Burnett, 2008; Webb, 1984), and general intelligence (Ambrosio, da Silva Almeida, Macedo & Franco, 2014) has been examined. Additionally, a positive relationship between field independence and success in programming is well-documented (Bishop-Clark, 1995). Some studies provide convincing evidence for cognitive effects of programming development, with major problem-solving skills and mathematical rigor being among the skills that are developed (Pea & Kurland, 1984).

2. Women's Underrepresentation in Computer Science

Over the last 25 years representation of women in computer science has been diminishing (Charles & Bradley, 2006; Cohoon, 2003; 2011; Dryburgh, 2000; Galpin, 2002; Hayes, 2010; Margolis & Fisher, 2002). Surprisingly, a persistent decline began in mid-1980s when the IT and ICT industries started to increasingly develop and prevail in worldwide economy. Especially in the United States, proportion of female postsecondary students of computer science at all degree levels began to fall. Since 2005 only 12-13 percent of female college students considered computing as their main discipline (Hayes, 2010). Moreover, merely 14-15 percent take the Advanced Placement test for computer science (SAT Data and Reports). Similar trends were observed in colleges and universities: between 1986 and 1996 women's share of bachelor degrees in computer sciences decline from a peak of 42,195 to 24,545 (Hayes, 2010), however this drop was observed only among bachelor female students, not for graduate programs. Hayes (2010) argued that this fluctuation pattern is distinctive for many scientific disciplines, including social sciences and engineering. However, a decreasing proportion of female representation is typical not for all STEM fields, but is visible merely in computer science. Improving gender balance has been reported in mathematics, physical science, biology and engineering; proportion of women in these STEM fields has been increasing systematically (Hayes, 2010). Some wind of change has been observed mainly in math. Gender similarities in mathematics performance have been reported as a trend for the last 20-years (Lindberg, Hyde, Petersen & Linn, 2010). However, results of this meta-analysis study showed a significant role of age and depth of knowledge tapped by tests as critical predictors for shaping the gender gap in math achievement. Male students from high school performed better in complex problem-solving tasks than female student did, which might serve as hypothetical explanation for the gender imbalance in computer science. Additionally, changes are also revealed on an academic level in the scientific stratosphere. The recent national hiring experiment conducted in United States (Williams & Ceci, 2015) revealed that identically-qualified female applicants for tenure-track assistant professorships from all STEM fields were preferred over male candidates. However, it is worth to note that cultural norms and political correctness might have a strong impact on this effect.

Thus, substantial and persistent falloff in female students' representation seems to be unique to computing. Consequently, female underrepresentation is reported among employees in computer or mathematical occupations. In the U.S. IT and ICT industry gender imbalance has been increasing for years – the U.S. Bureau of Labor Statistics data show that in 2008 and 2009 only 25 percent of computer and mathematical workforce were women. For the sake of the comparison, in 2000 it was 30 percent. Furthermore, gender imbalance in computing has been observed and analyzed in the global context and these investigations provide evidence for the gender gap in OECD countries as well (Charles & Bradley, 2006). In comparison with women's participation in other fields, women in computer science are underrepresented in every OECD country, though to varying extent. Between 2000 and 2012 in just five OECD countries (the Czech Republic, Germany, Portugal, the Slovak Republic and Switzerland) the proportion of women in life sciences, physical sciences, mathematics and statistics, and computing increased by at least 10 percent. Paradoxically, results from the Program for International Student Assessment consistently showed that, in general, girls reveal higher expectations for their careers than boys, and yet, on average, across OECD countries, less than 5 percent of girls report pursuing a career in computing and engineering (OECD, 2015). Only in Bulgaria, Indonesia, and Montenegro the number of female students planning their career choices in computer science and engineering outperforms the number of male students.

Hence, there is a well-justified and widespread concern with educational and workforce trends regarding gender differences in computer science. Noteworthy, if computer science is such a significant field for worldwide economy, this underrepresentation may have serious and negative consequences. But are those trends and effects generalizable to Poland as well? Is women underrepresentation also visible in Poland? The main aim of the following exploratory analyses is to review Polish data allowing us to outline a potential gender gap in computing in Poland. To this end, we focus on several sources. First, we demonstrate female student participation in the exam for secondary computer science schools. These data are presented in comparison with the gendered pattern of participation in the National Olympiad in Informatics. Then, we demonstrate how female undergraduates' participation in national contests for master's theses in computer science has evolved over time. Furthermore, we analyze the relationship between the number of female and male scientific advisors and the number of participating and awarded female contestants. Finally, based on data from the Foundation for Polish Science and the Polish Ministry of Science and Higher Education we demonstrate the proportion of female scientists in the STEM fields, with a particular reference to computer science.

Over the last ten years, the Polish exam for the secondary school certificate in computer science at advanced level was passed by 24,336 students. Noteworthy, the exam at its basic level was conducted only for a period of five years: between 2009 and 2014. Our analysis focuses on the advanced exam in computer science, because it contains tasks that test computational thinking and programming skills. Similarly, tasks and challenges at the National Olympiad in Informatics mainly require problem-solving abilities and computer programming competences above the more elementary knowledge and skills. Between 2005 and 2015 female students represented about 5 percent of all exam participants and about 4 percent of all Olympiad contestants! To put it differently, almost all contestants were males. These data are consistent with OECD results regarding female and male students' career choices. Figure 1 depicts participation in the exam and the Olympiad over the last ten years.

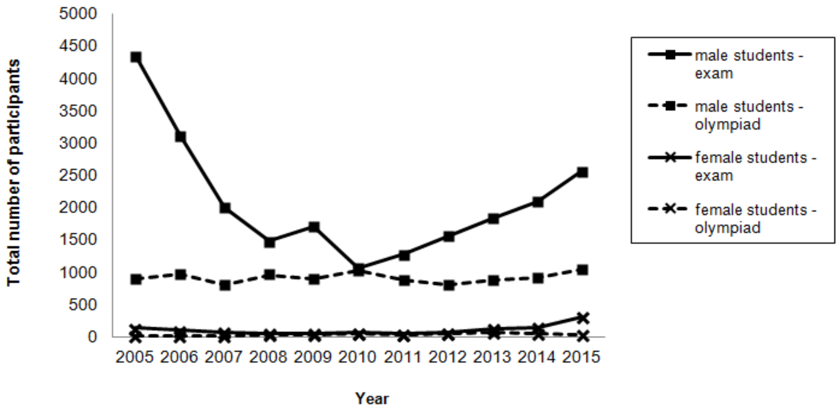

Figure 1. Participation in the exam for the secondary school certificate and the National Olympiad in Informatics, by gender

Source: Authors' analyses based on data obtained from the bureau of the National Olympiad in Informatics in Poland and the Central Examination Commission.

A particular falloff is observed from its peak in 2005, when 4,355 male students participated in the exam to 2010, when 1,074 boys took the exam. This fluctuating trend in the number of male students is worth its own research and explanation; we hypothesize that it stems from changes in the exam procedure on basic and advanced levels as well as demographic changes related to the number of students in each population cohort.

The National Olympiad in Informatics has been conducted since 1993. It is worth to note that, according to the Ministry of Science and Higher Education Report (2013), computer science is the most popular field of study among laureates of all national Olympiads in Poland. 164 laureates choose computer science as their field of study; this number is higher than in the other STEM fields. For instance, mathematics represents 60 and physical science represents 25 laureates respectively.

The last 22 years of the National Olympiad of Informatics show that among 19,776 participants, only 558 were females, which gives only 3 percent. Girls are consistently underrepresented on each level of the Olympiad: in the first round, the second round, and in the strict final. On the other hand, an interesting and a somewhat promising pattern has occurred among female students participating in the final of the National Olympiad in Informatics. In the last two years, the percentage of girls (16% in 2014, 26% in 2015) participating in the final is higher than the percentage of boys (10% in 2014, 8% in 2015 respectively). It begs to note, though, that until 2006 there were no female students in the finals (figure 2).

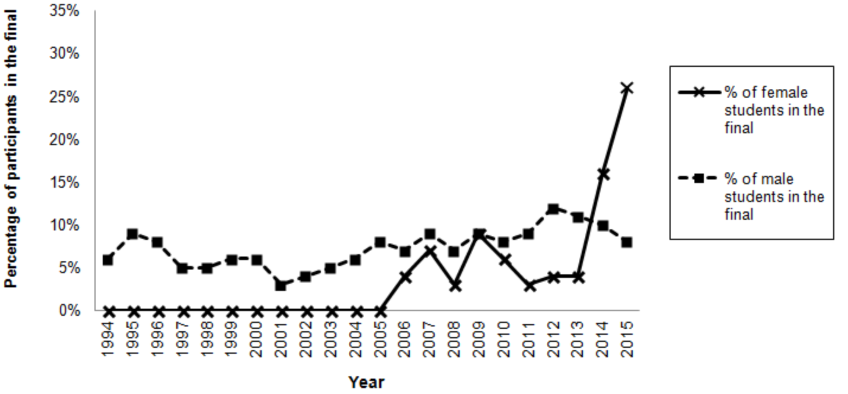

Figure 2. Participation in the Final of the National Olympiad in Informatics, by sex

Source: Authors' analyses based on the data obtained from the bureau of the National Olympiad in Informatics in Poland and the Central Examination Commission.

Gender gap in computer science in Poland is reported not only on the secondary school level, but also in academia. More specifically, unique data from the results of national contests for best master thesis in computer science demonstrate this gap as well. This contest is conducted by the Polish Information Processing Society since 1984. We analyzed data of 980 awardees (12% women) and 478 academic advisors (7% women) in a time-lagged perspective. The most interesting, although exploratory research question, was about the possible predictors of success of female students in this contest. Regression analysis on time-level data (year as a unit of analysis) predicted the total number of female laureates in each year, by three independent variables. Total number of female and male participants and the number of female advisors explained a large portion of variability in year-to-year changes in the number of female laureates (R^2 = .48, adjusted R^2 = .42). Obviously, the more women participated in the contest in the specific year, the more were awarded, but this effect was only marginally significant (β = .29; p = .08), and the higher number of male contestants, the lower chances for females to be awarded (β = -.74; p < .001). Importantly, however, the number of female scientific advisors in the specific year predicted the total number of females being awarded positively (β = .45; *p* = .03) (figure 3).

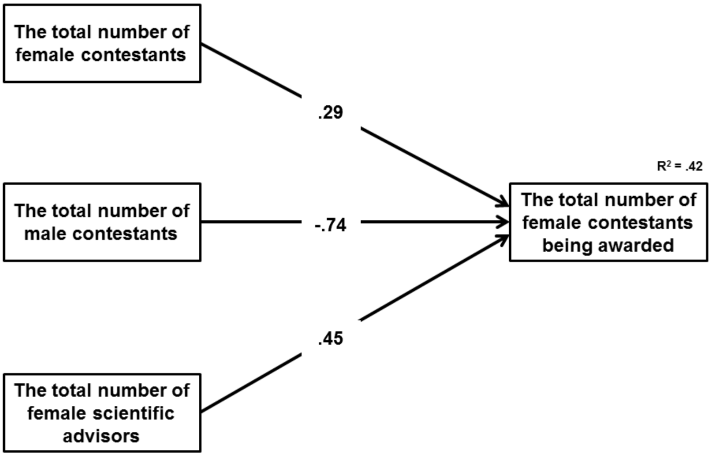

Figure 3. A Summary of the Regression Model Predicting the Number of Females being awarded in the National Olympiad in Informatics

Source: Authors' analyses based on the data obtained from the Foundation for Polish Science.

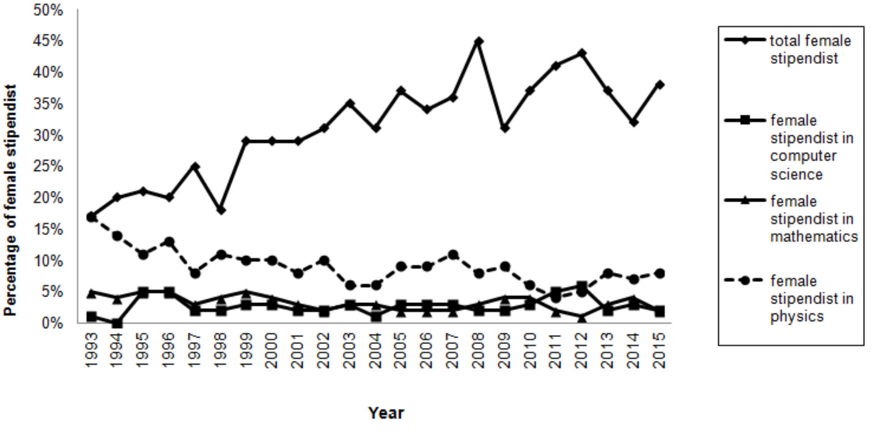

Figure 4. Trends of Females Awarded by the Start Program per field

Source: Authors' analyses based on the data obtained from the Foundation for Polish Science.

Data from the Foundation for Polish Science – the Start program for bright young scholars – provide additional arguments for women's underrepresentation in CS as well. Since 1993, the proportion of females awarded in all fields in the START program has fluctuated between 17 and 45 percent. However, when we focus on the percentage of women awarded in computer science, we found it extremely low, as between 1993 and 2015 it oscillates between 0 and 6 percent. Proportion of women awarded in mathematics and physics is also low, but it is still higher than in the specific case of computer science. These results are quite consistent with the general proportion of female students participating in the National Olympiad in Informatics (figure 4).

Obviously the close-to-the-floor number of females awarded in this contest tells us little about the reasons behind this finding and about the number of women who do apply for this program. Data from the National Information in Processing Institute provide evidence that gender imbalance is clearly visible among scholars in computer science, even when compared to mathematics and physics. Across each of these disciplines, representation of women shrinks as the educational level and position increases. The percentage of women earning PhD degrees in computer science is the lowest – 15% in comparison with mathematics 37% and physics – 29%.

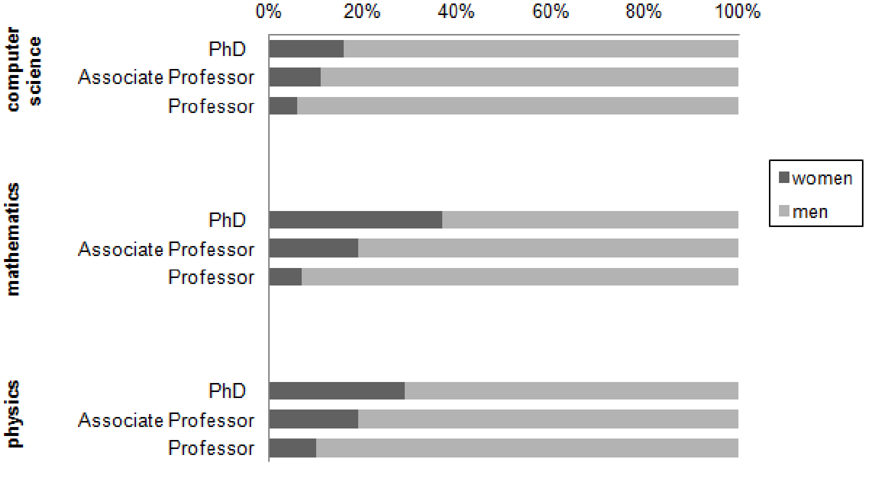

Figure 5. Percentage of female scientists in the STEM fields divided by the position

Source: Authors' analyses based on the data obtained from the National Information in Processing Institute.

3. Toward the Reasons behind the Gender Gap in Computer Science

What are the reasons and origins behind such a clearly visible female underrepresentation in computer science? Are the results nature-or-nurture based? What is the role played by the abilities and skills? What is caused by social influences, stereotypes or early teaching practices? The psychobiosocial theoretical approach (Halpern et al., 2005) offers a holistic and useful conceptual framework for the analysis of possible reasons behind the observed differences. Originally, this model was used to explain gender differences in math performance. Because computer science particularly draws on and requires mathematical thinking, we adopt Halpern's framework in an attempt to find the possible theoretical explanation of the gender gap observed in CS. The psychobiosocial approach shows how biological and psychosocial factors exert reciprocal effects on each other.

Although several studies have demonstrated differences in the number of males and females engaged in math and math-related fields (Ceci & Williams, 2010; Preckel, Goetz, Pekrun & Kleine, 2010), the review of research regarding gender differences in abilities leads to the conclusion that "males and females are similar on most, but not all, psychological variables" (Hayd, 2005, p. 581). Halpern argued that sometimes the differences promote women and other times they promote men, and pointed that "there is no evidence of a smarter sex" (Halpern, 2005, p. 54). In this section we selectively review findings from studies highlighting the role of spatial ability, psychosocial, and educational factors that bear a strong impact on mathematical and computer science proficiency as well.

Although several biological theories exist that underlie gender differences in math-related disciplines, the most popular biological explanation of sex differences is the so-called 'hormones hypothesis.' Specifically, mediating role of testosterone, estrogen and progesterone for both sexes throughout life span is highlighted. The controversial Geschwind's (1984) theory offers an explanation based on prenatal brain development and implies sex differences (see also Karwowski & Lebuda, 2014; in press). According to this approach, exposure to higher level of prenatal testosterone correlates with right-hemisphere dominance and left-handedness among males. Increased likelihood of being left-handed by men than women was confirmed in several studies. At the heart of

Geschwind's theory is the assumption that men's cognitive ability pattern will be more directly linked with right hemisphere functioning. From this point of view, men's higher scores in spatial tasks are believed to result from exposure to testosterone in the prenatal environment. Regardless of the controversies and some false premises regarding the dichotomization of hemispheric functioning in the presented approach, modern psychology and endocrinology provides evidence that hormones impact gender differences in spatial ability (Hooven, Chabris, Ellison & Kosslyn, 2004). In the deterministic context of biological explanations, it is worth to notice that the level of hormones is not fixed, but it changes during the life span. Furthermore, hormone fluctuations are observed especially in adolescence and over the menstrual cycle among women.

Spatial abilities play a critical role in performance in mathematics and computer science. For more than half a century spatial abilities have been linked to mathematical proficiency (Wai, Lubinski & Benbow, 2009; Wai, Lubinski, Benbow & Steiger, 2010). Lubinski (2010) even argued that the relationship between STEM and spatial ability is a "sleeping giant for talent identification." Although the finding that males hold better spatial abilities than females do is well-established, literature provided evidence for developmental changes of gender differences in this respect. A lack of differences among males and females before adolescence is usually found (Levine, Huttenlocher, Taylor & Langrock, 1999), with children's results being virtually identical: a finding replicated in meta-analysis, which analyzed gender differences on the three dimensions of spatial ability: mental rotation, visual perception, and visualization (Voyer, Voyer & Branden, 1995). Interestingly, the extent of difference in those three aspects was found to increases distinctly with age. Systematically lowest differences were observed among children under 13 years of age, higher among 13 – 18-year-old individuals, and the highest among participants older than 18 years of age. Hence, these results explain little in relation to our main point, i.e. the possible reasons behind gender differences in computer science – presence and successes. Furthermore, there are good reasons to believe that social factors may be equally, or even more, important while forming interest toward the field and differences in achievement in this field. For instance, although there is a lack of difference between boys' and girls' performance in mathematical thinking (TIMSS study) before adolescence, such differences do exist in adolescence (PISA) (Else-Quest, Hyde & Linn, 2010).

According to Halpern's model, biological contributions and psychosocial factors play a critical role in elucidating gender differences in spatial ability. For instance, gender differences in spatial abilities have been tested with regards to Nash's (1979) gender-role mediation hypothesis on cognitive development. A meta-analysis (Signorelli & Jamison 1986) revealed substantial correlation between spatial ability (space perception) and the more masculine traits in self-description, especially among girls in adolescence (r = .47) than women (r = .20). Additionally, a weak but significant correlation was observed between masculine gender identity and mental rotation ability for both men (r = .16) and women (r = .10). Other studies examined gender differences in spatial abilities drawing on two competitive theoretical frameworks (Signorella, Jamison & Krupa, 1989). The first, based on Bem's (1981) theory, examined the mediating function of activity between psychological sex and spatial abilities. Thus, it was assumed that being an individual with more prevalent masculine traits should translate into higher activity in tasks requiring spatial ability, and consequently the level of these abilities should increase. In turn, according to Spence's (1985) theory, the level of spatial abilities is rather a gender attribute than a result of activity. Hence, psychological sex and activity are independent predictors of spatial abilities. Results of Signorella and her colleagues' studies (1986) are in line with Spence's rather than Bem's theory assumptions. Results of the more recent meta-analysis estimated the effectiveness of spatial ability trainings at g = 0.47 (Uttall, Meadow, Tipton, Hand, Alden, Warren & Newcombe, 2013). The authors noticed that trainings bring significant benefits especially for children and people with lower baseline of spatial abilities. Interestingly, no gender differences were noted.

However, to see the 'big picture' of the gender gap it is worthwhile to extend the potential explanations regarding gender differences in math-intensive fields also beyond spatial abilities and to analyze the non-cognitive constructs as well. In debates about gender differences in math-related fields, the impact of psychosocial and non-cognitive factors was neglected by educational researchers and psychologists, while there is clear evidence for several factors shaping the gender imbalance in computing. The most commonly reported "candidate predictors" are: self-efficacy (Bush, 1995; Cassidy & Eachus, 2002; Durndell & Haag, 2002; Saleem, Beaudry & Croteau, 2011), computer anxiety (Hua, Chen & Wong, 1999), and attitudes towards computers (Shashaani, 1997).

On average, girls reveal lower computer self-efficacy, higher level of computer anxiety and – in comparison with boys – negative rather than positive attitudes towards computers. A meta-analysis of gender differences in computer-related attitudes and behaviors (Whitley, 1997) demonstrated significant differences in sex-role stereotypes, self-efficacy, and affective responses. Interestingly, students' age was one of the crucial moderators. The increasing effect size of gender differences with age suggests that attitudes towards computers are shaped during socialization.

The concept of self-efficacy, defined as people's beliefs about their abilities to execute a particular behaviour successfully, seems to be among the crucial factors that stand behind gender differences in computer science. According to Bandura's social cognitive theory (1977; 1986; 1997), mastery experiences, vicarious experiences (observing others' successes and failures), social persuasion, and physiological experiences are four major sources of self-efficacy. It has been demonstrated that lack of previous experience with computer programming negatively translates into female students' motivation (Papastergiou, 2007; Margolis & Fisher, 2002; Saleem, Baudry & Croteau, 2011), while prior experience and encouragement has been revealed as a significant predictor of attitudes towards computers; male students reported higher degree of experience in programming compared with female students (Busch, 1998). Basing on the results of more than 230 interviews with female and male students of computer science at Carnegie Mellon University from 1995 to 1999, Margolis and Fisher (2002) suggested that experience with computers at home, the impact of peers, parents or teachers, and the presence of positive role models play a critical role for future career choices and pathways. In accordance with the value-expectancy theory (Eccles, 1994), parents and teachers might have a positive impact on youths' abilities and value beliefs in computer science. The following are but a few examples of teachers' strategies that may build students' sense of the importance of the field of computers: providing learning opportunities, encouraging engagement in computer science activities, expressing positive expectations and positive values about the importance, usefulness and appropriateness of computing, and by modelling computer and technology use. However, still little is known about students' classroom experiences and the role of their teachers. Results from various studies are inconsistent. For instance, while Shashaani (1993) showed that female students perceived genderstereotyped views in their teachers' behaviors, Young (2000) reported that female students felt encouraged to computing by teachers. Vekiri (2010) investigated relationships between female and male students' value and efficacy beliefs about computers and computer science, and the perceived parental support and teachers' expectations. As hypothesized, teachers' expectations predicted especially girls' self-efficacy. Interestingly, this finding is consistent with recent evidence that students' gender may moderate the relationship between teachers' ratings of students' potential (i.e., creativity) and students' domain-specific self-efficacy (Karwowski, Gralewski & Szumski, 2015). The teachers' effect was significantly stronger for female than male students. Gender difference in the self-concept of computer and math abilities has been examined in the longitudinal design among Spanish secondary school students (Sáinz & Eccles, 2012). A higher self-concept of computer ability was observed among male students and it increases across time, while among females, the self-concept decreased. Importantly, male students have had higher self-concept of math ability, despite the absence of gender differences in math achievements. Self-concepts of computer ability was a relevant predictor of the intention to pursue ICT-related studies and a mediator between gender and the intention to future career choices in ICT.

Finally, domain specificity of computer science and its links with both math and technology, exposes females to negative stereotypes with regard to their competences and cognitive abilities in these domains. In turn, negative stereotypes about female mathematical and computing abilities reflect in their performance, achievements, and aspirations. Even very subtle priming, i.e., being exposed to an object stereotypically and conceptually close to computing (e.g., Star Trek poster in the classroom) translated into lower interest in computer science among females (Cheryan, Plaut, Davies & Steele, 2009). In turn, women's awareness and conviction of being marked as "poor in math and computer science" may bear a substantial negative impact on their cognitive functioning and behavior. Interestingly, Nguyen and Ryan (2008) showed that even girls who were convinced that they were good in math revealed strong identification with this field, and finally were good in math, were still at risk of the stereotype threat (Spencer, Steele & Queen, 1999). A study conducted among Australian senior high school students revealed that aversion to computers and perceiving advanced computing subjects as boring was a major factor that discouraged female students from computer science (Anderson, Lankshear, Timms & Courtney, 2008). A survey of 462 middle and high school students examining the role of major factors on gender differences in attitudes toward computers (Young, 2000) showed that the higher level of confidence in being "technological savvy" among male students was linked with their computer skills. These results are consistent with data from the International Computer and Information Literacy Study (ICILS), which indicate that girls reveal lower confidence than boys in their competence regarding such advanced tasks as building a webpage or programming a computer. Moreover, in Young's study male students strongly agreed with the opinion that the field of computer science is male-dominated. Indeed, computer science is perceived as gendered-stereotyped, male-dominated field in the area of public consciousness, mass media, and advertising as well (see Tympas, Konsta, Lekkas & Karras, 2010, for a review). Perception of computer science as "guy stuff" and male "geek culture" of computing strongly influence girls' future career choices (Margolis & Fisher, 2002). Finally, Cohoon (2006) noticed that culture and social structure are major factors that develop the gender gap. According to Kopciewicz (2013), in the scientific discussion about the gender issue of being 'poor at math' and likely also in other math-intensive fields, the context of a "critical filter" associated with unequal access to higher education and employment, should be taken under consideration.

Cultural beliefs about gender and computing differ between countries. For instance, gender balance in computer science emerged in Malaysia, where computing is perceived as a good career pathway for females (Lagesen, 2008) or in Turkey, where women are poorly represented on the higher education level. Shashaani and Khalili (2001) provided evidence that Iranian female students believed more strongly in equal gender ability and digital literacy, but reported low confidence in their own ability. Moreover, both male and female students believed equally in the positive effects of computers on individuals and society. Regardless of cultural differences in females' attitudes, self-efficacy and career choices in computer science, the image of a male computer nerd is still popular in the media. Although between WWII and mid-1980s women played a significant and positive role in the history and industry of computing (Abbate, 2012), contemporary public consciousness has it that females in IT are perceived as a weird minority. Still, computer science is perceived as an archetypical example of a technoscience that has excluded women (Lagesen, 2007).

4. Discussion

We opened this paper with anecdotal evidence of the great achievement of Ada Lovelace – in several respects "the founding mother" of contemporary computer science. However, despite Ada's discoveries, the whole field of programming, computing, and creating with the use of computers is not only perceived as "the males' world," but there are indeed reasons to believe that the gender gap in this respect is growing rather than declining. Data from different sources we were able to use, i.e., those showing differences in the number of males and females getting the informatics exam at the end of the high school, those participating and being awarded in the "National Informatics Olympiad," those who win the fellowship in the prestigious Start stipend from the Foundation of the Polish Science, and finally – those who take university positions in computer science, show the very same story: indeed, not only there is a deep gap, but also we have very little arguments to believe this gap may be easily filled.

Hence, our overview and discussion focused mainly on the possible reasons behind those differences. We perceived the psychobiosocial model (Halpern et al., 2005) as useful while organizing our arguments. Starting with this model we briefly analysed the role of biological, psychological, and social factors in gender differences in the presence and successes of both genders in computer science. Although some arguments about the possible biological underpinnings of spatial abilities should not be ignored – especially keeping in mind the role spatial abilities play in math and computing, our overview rather highlight the complex role of self-beliefs (i.e., self-efficacy) and social factors forming those beliefs as potential explanatory variables. There are empirical arguments that even the gender gap in spatial abilities may be effectively reduced during quite an informal training, e.g., by playing action video games (Feng, Spence & Pratt, 2007). However, in real-life conditions, playing such games is much more typical for boys than girls.

According to the theories of self-efficacy (Bandura, 1997), self-perception of one's abilities is crucial for initiation of an activity, motivation to continue in face of failures, and eventually – in explaining variability in achievement. There are also convincing arguments that at least four different sources shape our self-efficacy. These are: (1) mastery experiences – previous successes interpreted as personally meaningful,

(2) vicarious experiences – the role of modelling and observation of others, (3) social persuasion – i.e. the role of significant others, like parents, teachers or peers, in shaping the level of self-efficacy and (4) physiological experiences – arousal and affective reactions related to activity in a certain field. All these four wide groups of predictors play a role in understanding why there are so few women in science in general, and in computing in particular. Due to the less intensive activity in computing or even playing computer games, girls have fewer opportunities for mastery experiences – a crucial factor in the process of forming self-efficacy. As their friends are rarely engaged in that sphere as well, this factor also gives them restricted opportunities to observe, compare, and being modelled by highly skilled women-programmers. The social persuasion factor, i.e., emotional and rational arguments about the importance of the field provided by teachers, parents or peers also may exert a rather limited influence, while the level of their computer anxiety, i.e., negative physiological experiences, is usually higher (Gilroy & Desai, 1986). Consequently, all these building-blocks of computer self-efficacy seem rather to hinder than to strengthen it among females. And going further, low level of self-efficacy may explain why girls and young women rarely choose the high-school or university courses related to programming, and then think about career related to this field.

Re-analysis of the data obtained from the Polish National Informatics Olympiad demonstrated an interesting pattern: while the number of females awarded in this contest was clearly predicted by the number of participating females (positively) and males (negatively), the significant and strong predictor of women's successes was the number of female scientific advisors. When interpreting this finding consistently with self-efficacy theory, one may say that such advisors very likely serve as role models and show on their own example how to effectively function in the programming world, so strongly dominated by males.

To conclude, we should get back to our introductory arguments highlighting the growing role of computer science in contemporary world and the risk of missing opportunities that stem from women's underrepresentation here. To put it simply: to have enriching solutions in the field of computer science, more differentiated perspectives are necessary. Women programmers may obviously enrich this perspective.

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