# Examining Unequal Gender Distribution in Software Engineering

Alex Murphy[1], Ben Kelly[1], Kai Bergmann[1], Kyrylo Khaletskyy[1], Rory V. O'Connor[1,2], and Paul M. Clarke[1,2(✉)]

[1] School of Computing, Dublin City University, Glasnevin, Dublin, Ireland
{alex.murphy287, ben.kelly45, kai.bergmann3, kyrylo.khaletskyy2}@mail.dcu.ie, {rory.oconnor, paul.m.clarke}@dcu.ie
[2] Lero, The Irish Software Research Center, Dublin, Ireland

**Abstract.** This paper investigates the biological, psychological and societal reasoning for the disparity of females in the software engineering industry and how a more diverse workforce can have an advantage in this sector. Studies show that diversity in a company positively correlates to its financial profits. Furthermore, a severe lack of women in software engineering causes companies to limit themselves to smaller talent pools, decrease the creative outlook on fresh ideas and resolution of problems. There are superficially inherent reasons why computing appeals to men more than women, observations in multiple reports suggest that men may have a small advantage when it comes to mathematical and problem-solving skills. Additionally, it is elsewhere suggested that females interests reside in other fields related to 'people', whereas males are generally more interested in 'things'. However, while societal factors and bias plays a role in the discouragement of women from the software engineering industry, studies have shown that countries with more gender-inegalitarian societies show an increase in the number of women in software engineering and STEM. This may imply that gender disparity in software engineering primarily emerges from personal choice rather than any discrimination or stereotyping.

**Keywords:** Gender distribution · Software engineering

## 1 Introduction

Recent reports contend that women continue to be severely underrepresented in technology-related fields. Whereas in 1985, women accounted for 37% of all computer science graduates, by 2011 this number had dropped steadily to 17%, with the result that women now make up only 25% of the computing workforce [13]. Not only is there a disparity of women in software engineering, but this is also seen throughout the STEM (Science, Technology, Engineering and Mathematics) subjects in universities and as a result in the workplace. While this report is focused on gender distribution in software engineering, evidence suggests that the gender representation disparity is more broadly applicable across STEM. This report aims to provide a consensus and insight into the reasons behind the gender disparity in the software engineering industry


A. Walker et al. (Eds.): EuroSPI 2019, CCIS 1060, pp. 659–671, 2019.
https://doi.org/10.1007/978-3-030-28005-5_51

and how it can be addressed. The underlying question is, are women forced out of computing due to stereotyping and discrimination or is it simply their personal and psychological interests that drive them away?

## 2 Related Literature

### 2.1 Methodology

This research has been implemented in the context of a four-person team as part of a final year computing-based undergraduate program. A multivocal review including both peer reviewed papers and other non-academic sources was undertaken using searches on google.com and google scholar. Where papers of interest were identified, they were incorporated into the research (and a process of snowballing was enacted to pursue any related information included in any given source under analysis). The topic was examined under four key sub-topics: psychological/biological gender differences, the history of women in computing, biases and stereotypes, and the benefits of gender diversity. These sub-topics were agreed upon early in the research process, through a combination of general research into the topic, weekly feedback sessions with out supervisor, and general research management within the research team.

Given that the topic under study is so large and the research being subject to the constraints of an undergraduate assessment (with just 6 weeks to complete), the primary objective of the exercise was to learn as much as possible about the topic in the time available and to present the findings in this research paper. It was not intended that a comprehensive and highly systematic literature review be undertaken as the time required for such an exercise would have far exceeded the available time. The impact of these limitations is discussed in Sect. 4. However, it was intended to examine certain key sub-topics within the software engineering gender distribution debate and to bring together a coherent research paper to summarise the work.

Each team member selected a key sub-topic and commenced a review of the sub-topic, gradually synthesizing an understanding of their subtopic, Ultimately, and in collaboration with their team, an overall understanding of the topic was also obtained. When incorporating non-peer reviewed sources, the team exercised caution, for example, only including websites where there was some level of administration/moderation, most of these being major newspaper websites.

### 2.2 Inclusion/Exclusion Criteria

Papers/articles were included if they provided a substantial or interesting perspective on one of the sub-topics. Non-peer reviewed papers were more likely to be rejected as mentioned above, but the overall inclusion criteria was one of relevance and reliability. Given that there was a requirement to synthesise an understanding across the team and write up a research paper (this along with attending to other modules in the undergraduate degree program), it was necessary to simply conduct as much research as possible but to not exceed 4 weeks in doing so. The result was the identification of 152 sources of interest, and these formed the basis for the analysis and synthesis reported upon herein.

### 2.3 Cited Peer Reviewed Papers Breakdown

| | Number of papers identified | Number of papers explicitly included | Total |
|---|---|---|---|
| ACM | 21 | 5 | 26 |
| Journal of Intelligence | 8 | 1 | 9 |
| Journal of Science | 6 | 1 | 7 |
| Vocational Behavior | 5 | 1 | 6 |
| Sage Journals | 9 | 1 | 10 |
| Child Development | 2 | 1 | 3 |
| Technology & Culture | 4 | 1 | 5 |
| GATES | 3 | 1 | 4 |
| Population Space and Place | 1 | 1 | 2 |
| Gender, Science & Technology | 1 | 1 | 2 |
| Computing Sciences in Colleges | 7 | 1 | 8 |
| Social Development | 3 | 1 | 4 |
| Canberra: Australia Government P.S. | 1 | 1 | 2 |
| Journals of Economics & Business | 11 | 3 | 14 |
| Journals of Educational Discipline | 16 | 3 | 19 |
| Journals of Psychological Discipline | 19 | 6 | 25 |
| Total | 123 | 29 | 152 |

## 3 Analysis

### 3.1 Psychological/Biological Gender Differences

Before examining the software engineering gender distribution, it is vital to discuss the physiological differences between men and women. This will give us an insight into the collective subconscious psyche and decision making of each gender, subsequently, we can elaborate possible reason(s) for the low proportion of women in software engineering. Software engineering and computing, in general, do not demand pure physical strength unlike other jobs in the field of physical labour where men may some endemic advantage over women. Gender differences have been suggested in cognitive ability such as quantitative, mathematical, problem-solving and visuospatial awareness competence which directly correlate to typical software engineering skills [4]. A dated longitudinal study on mathematical gender differences suggests that until grade 5 (age 10–11) in school, girls and boys do not show any difference in mathematical achievement but thereafter (grades 7, 9, 11) boys pull ahead of girls [1]. In a similar study performed on the American SAT exams, men surpassed women overall but the difference was greater on items requiring spatial skills, shortcuts, or multiple solution paths [4]. Studies also show that men have a 4% higher average mathematics result in the SAT exams over the past 50 years [11]. This trend continues in the Irish Leaving Certificate, based on the statistics provided by the State Examination Commission twice as many men receive an A ($\geq 85\%$) in higher level mathematics than girls [12]. In contrast, women outperformed men on problems requiring verbal skills or mastery of classroom-based content. Tempting though it might be to confer certain basic biologic advantages on one gender over another on the basis of these various studies, we must not forget that this data does not confirm the existence of any such advantage, this evidence merely reports on the general outcomes of analyses of gender performance in domains related to software engineering. While basic biological differences might account for the differences, it could just as possibly be the result of societal stereotyping and role models over time.

Quantitative and problem-solving tasks related to non-classroom-based content correlate to typical software engineering tasks and would give men a marginal advantage in the field of software engineering. Studies have reported that boys start to present with increased competitive tendencies in adolescence [2] and this might fuel competition between boys to excel at subjects wherein they have a perception of relative strength. While these differences at a gender performance level have been independently reported in multiple studies, it is also known that environmental influences such as parents, teachers and societal expectations play an important role in defining individual objectives [1, 6]. It is therefore unsurprising to also find that implicit biases negatively influence female interest in STEM fields [44]. This might account to some extent for the finding that "only 27% of men reported not using a computer on a weekly basis, compared to 55% of females surveyed" [13]. This finding itself might provide some explanation for the reported phenomenon in $2^{nd}$ year elective computing modules in American colleges, whereby some girls were reported not to have the requisite knowledge of computers in order to have a full understanding of the computing course when compared to their male counterparts [3]. It seems therefore that in some cases at least, and for reasons which may be multifaceted and inherently complex, females may already lag their male counterparts in some basic computing know-how at the point of arrival to third level education.

Of particular interest, multiple studies in gender differences in self-perceived computer competency and efficiency show that men report relatively higher levels of confidence in performing various computer tasks such as word processing, email, web browser and file transfer [8, 9]. However, these studies have also demonstrated that confidence is not matched with actual competence, and that in terms of general computer software use, no significant gender competence differences were observed. This is a perplexing finding with no single, obvious explanation. The authors suggest that perhaps at some level, males are less concerned about working with technology with which they have only limited competence (equipped as they are with a coping selfconfidence-led mechanism). Females, in contrast and on the basis of this same evidence, may be better able to identify their competency level in computing software usage. Beyond software engineering, there are various fields where women are reported to have a performance advantage over males, but any such analysis is beyond the strict scope of this research.

While the various paragraphs above outline some findings from related literature into gender performance in computing/software/STEM arenas, the psychological aspects are perhaps the most instructive. And the essential finding that women report a relatively lower level of interest in STEM and computing must weigh heavily on their underrepresentation in the field. For example, when observing Holland's hexagon or RIASEC (Realistic, Investigative, Artistic, Social, Enterprising and Conventional) model it can be seen that high gender differences occur in the 'people–things' dimension. From this, we suggest, it can be interpreted that it is the male interest in 'things' that leads them into STEM fields. We furthermore see that gender interest differences appear to be consistent across all cultures and times, which may support a biological finding that contradicts social role theory or any societal influences [2]. Interestingly, this same study reports that the interest gap increases with more gender-egalitarian societies, as might be demonstrated by higher proportions for women in software development in less developed gender-inegalitarian countries such as India [10]. Women in these populations who are perhaps concerned about being hired into other domains, may be choosing in larger numbers to study in a field with a high female graduate conversion rate. "Women in countries with higher gender inequality are simply seeking the clearest possible path to financial freedom. And often, that path leads through STEM professions." [15].

### 3.2 History of Women in Computing

Perhaps the gender skew observed in the contemporary software industry can be explained when we look at the changing role of women in the patriarchal structure over the past hundred years. At the beginning of the 20th century, women were confined to their homes and were responsible for raising children while men were otherwise employed outside of the home. In recent years this trend has shifted in more developed nations, where both parents may work full-time outside of the home while their children are being minded and nurtured by a third party. During the world wars of the 20$^{th}$ century, in addition to looking after the home women also provided essential services such as phone operators and 'computer coders' [18, 29, 33]. During the 1930s and 1940s the invention of household refrigeration, contraception and other innovations, resulted in increasing numbers of women entering the workplace, but not in the software engineering industry [16].

Although there were flashes of women flourishing in computing over the years, notably Joan Clarke who cracked the Enigma code in the 1940s, Admiral Grace Hopper who developed the first computer compiler in the 1950s, the six female programmers of the ENIAC in the 1980s; they were brief. Despite this, in the early 1980s software engineering was becoming a common path for women, and in 1984 women's participation in computer science degrees grew to 37% (twice of what it is today). Programming was hailed as a more interesting version of secretarial work by the popculture cosmopolitan magazine [39], typifying the overall consensus of the profession at the time (which lauded hardware as the main thrust of the computing industry). Thereafter female participation declined, and with the monetary explosion of Silicon Valley, more men pursued software development (perhaps, it might be suggested, pushing women out of the industry). And although female participation in ICT (Information and Communications Technology) has increased since 1995, the general industry ratio of male to female workers has not shifted [37].

In a study undertaken by the University of Liverpool, we see the specific breakdown of roles within the software industry. Only 5% of gaming programmers are female, while only 2.4% of the women in the study were software engineers [38]. Given the recruitment challenges that pervade the software development industry, and the many noted advantages to having a diverse workforce (which are discussed later), it is perhaps surprising that more significant efforts have not been imagined to successfully attract greater numbers of females to software engineering. The Computing sector is the fastest growing industry in Europe, with Ireland being the fastest growing economy in Europe throughout the past four years [14, 40]. This creates a huge appetite for software graduates, which at present is significantly undersupplied.

How might greater numbers of females be attracted to software engineering? As we have shown, two of the main reasons inhibiting women entering the software engineering industry are 1. Somewhat flawed perceptions of capability in respect of computing; and 2. Stereotyping that women may encounter for 'straying from the norm' [28]. It has been reported that females may tend to incorrectly believe that they will not be good at computing [8, 9]. The manifestation of stereotyping and discrimination is discussed below but it is clear that both of these issues ought to be addressed if we are to see a greater balance of women in software engineering.

### 3.3 Investigating Biases and Stereotypes

As we have shown, bias has been cited as a causal factor for low numbers of women entering software engineering and STEM fields, with claims that stereotypes and social attitudes have been dissuading women from these particular fields. According to a 2017 study, there are six explanations for women's underrepresentation in STEM fields. Only one of these reasons is gender-related stereotypes and biases [44].

Some studies have indicated that imagery used within computer science degree programs can be insensitive towards women, creating an uncomfortable environment, leading to female underperformance [41]. A prime example of such imagery is the 'Lena' image, originally a centerfold in a 1972 edition of *Playboy* magazine. "It is [perhaps] not surprising that the (mostly male) image processing research community gravitated toward an image that they found attractive" [41, 46]. Use of such images can be considered degrading to women and the physical objectification of a woman's body can result in reduced female cognitive performance [47]. This creates an environment where men are set up to perform better than their female counterparts. It has been shown that objectifying images of women may cause both males and females to associate reduced competence levels with women whose physical qualities are emphasized [17]. This is significant because studies have shown that faculty expectations of women directly influence their performance in computer science [41].

Stereotypes also play a part in making women think that a future in STEM fields would not be something to which they are suited. It has been shown that people, to different extents, have a 'science-is-male' stereotype which increases as the field becomes more science intensive. The prospect that men hold such stereotypes has been suggested to cause women to decide not to continue pursuing a career in software engineering and having them drop out of computer science courses [7]. Computer and information sciences have been found to have a strong stereotype of being more for men by nearly a full standard deviation above the zero-point of no stereotyping [42]. These stereotypes are reinforced by men predominating on the front of software packages, the main character in video games tend to be male and most computer salespeople tend to be male, which stops young girls from getting involved for fear of being stereotyped as a 'nerd' [43].

A study undertaken in two Malaysian computer science programs where the majority of faculty lecturers are female found that no gender bias with regards to computer science/IT is perceived by young Malaysians [45]. This suggests that gender bias has an effect on the proportion of females that choose a career in computing, and that the removal of such biases would have a positive effect on gender distribution within these fields. Male students in Malaysia tend to start their degrees with more computer skills than their female counterparts, but this difference in initial ability does not result in male students outperforming female students [45]. This shows that initial skill level does not determine concretely how successful one will be in their studies.

Due to the lack of females in computing, companies may be more inclined to hire females over males. This can have an unintended negative effect because it ought to be in a company's best interest to hire the best candidate possible for the position regardless of their gender (though analyses of 'best interest' might be non-trivial). If the candidates must be female or if one gender is favoured over another then companies may be restricting their scope on an already limited talent pool. There are insufficient computing graduates and as stated by Jordan Peterson, "if you start putting arbitrary restrictions (such as gender) on … hiring, you're going to end up not finding the ones [that do exist]" [23]. In terms of University, we can look at Carnegie Mellon University in Pittsburgh, Pennsylvania who have a near 50:50 gender split in their school of computing [26].

### 3.4 Benefits of Gender Diversity

To aid in understanding the possible advantages of gender diversity in the software engineering sector, we can examine the effects of a more gender diverse workforce in other career paths that share similar management and workflow techniques as software engineering. A research paper from *McKinsey & Co.* compiled in 2015 titled 'Diversity Matters', reports on how diversity affected financial performance using both leadership demographics and financial data of hundreds of companies in various countries [30]. Analysis of the data from the group of 366 companies revealed a significant connection between diversity and financial performance. Companies in the top quartile for gender diversity were 15% more likely to have financial returns that were above their national industry median [30]. 'Diversity Matters' reports a positive correlation between gender diversity and financial performance, but it does not investigate the possible causes for this. It is suggested that a strong focus on females and ethnic minorities increases the available talent pool to companies. Diversity may, it seems, foster innovation and creativity through a greater variety of problem-solving approaches, perspectives and ideas.

In 2017, the Royal Academy of Engineering in the UK published a research paper titled ‘Creating Cultures Where All Engineers Thrive’ [31]. This paper acknowledged the need for a more diverse workforce and is based on the personal responses of 6,799 people currently employed in various engineering roles throughout the UK. The data collected from this survey spanned various levels of expertise, with over 66% of candidates being members of professional engineering institutions and 48% being professionally registered within the UK. The research paper revealed that morale within the workplace increased in conjunction with an increase in diversity, along with the performance of engineering employees. 80% reported increased motivation, 68% increased performance and 52% increased commitment to the organisation.

In 2018, *McKinsey & Co*. published another research paper: ‘Delivering Through Diversity’ as an extension to their previous publications. This paper describes the correlation between diversity (of both gender and ethnic backgrounds) and financial profitability, with a dataset of more than 1,000 companies spanning 12 countries. ‘Delivering Through Diversity’ reaffirms earlier findings and reinforces the importance of a gender diverse workforce within a company, including software engineers. Almost three years later, this number rose to 21% from the original 15% and continued to be statistically significant.

From analyzing the varying research papers mentioned above it is clear that the diversity of gender within all business types, and by extension software engineering, is of significant importance. Given the lack of women in software engineering work environments, companies are limiting themselves to smaller talent pools, less motivated software engineers, sub-optimal creative problem-solving and are ultimately forfeiting a large performance gain. Such statistics demonstrate how severe the disadvantage is when a company does not have a gender diverse workforce.

## 4 Limitations of Research

As a basic limitation, this work was undertaken primarily by a team of undergraduate students largely unskilled in research. However, intensive research training and advice was provided at the outset of the assignment and on a weekly basis throughout the 6-week research period, which equates to a total of 24 person weeks (albeit part time) to investigate the topic. Inevitably therefore, there are some limitations related to research experience and available time. The time constraint represents one of the major reasons why just four sub-topics were selected for investigation. Had more time been available to the researchers, it is possible that further sub-topics could have been investigated and indeed, the very selection of these four sub-topics could have been further validated through both deeper and broader initial research. However, this limitation in respect of technical academic rigour, it is felt, does not diminish the relevance of the work as a useful contribution to the software engineering gender balance debate. Furthermore, a systematic mapping review might have been useful to reinforcing the methodology employed.

The authors also wish to highlight that while there are a great many publications readily presenting in respect of the general STEM gender diversity debate, there would appear to be relatively few works dedicated specifically to software engineering gender diversity. This unfortunately means that many of the works identified in this research are more general than just the software engineering field and as such interpretations inferred from the general back drop might be lacking precision in the context of software engineering in certain respects. The specifics of gender distribution will ultimately vary from sub-field to sub-field, even within STEM, and therefore some interpretations may not be entirely accurate.

While there are benefits to adopting a multivocal literature review, there are some limitations associated with the approach. Primary among these is the unavoidable fact that once non-peer reviewed sources are considered, it becomes manifestly more challenging to incorporate the vast volumes of material available from general internet-based sources. Therefore, and in consideration of the undergraduate and time-bound nature of this research work, there are methodological frailties in the work. Nevertheless, a loose methodological structure was adopted that is considered to be sufficiently rigorous to deliver meaningful and useful content in respect of the research subject.

## 5 Future Work/Directions for Future Research

If there is one major finding from this work it is that despite the much reported and generally recognized gender imbalance problem in software engineering, there is relatively little direct academic research into this problem. The contributions to date seem to have been be led by the industrial community. This is perhaps surprising given the gravity of the problem, or it might be the result of a male-led software engineering academic community who have up to this point been under-concerned about the impacts of gender imbalance. The authors strongly encourage further research in this space and intend to undertake some of this work in our own university (and beyond).

Many future research perspectives can be pursued, and we would suggest that a good starting point would be an examination of the reasons for relatively low levels of female applications to 3rd level computer and software engineering related degree programs. Certain important information can be obtained through surveying of male and female university software engineering populations (and also later in industry) but given that the supply-side problem is already clearly evident at the entry point to 3rd level, we suggest that this is a fruitful area for initial inquiry.

## 6 Conclusion

This paper has investigated the biological, psychological and societal reasoning for the disparity in women in the software engineering industry and how a more diverse workforce can have an advantage in this sector. This, we suggest is very important, given the fact that software development is a complex socio-technical undertaking [50], it is challenged to constantly evolve [5], and there is a diversity focus in leading software engineering international conferences [51]. Indeed, even the very language adopted might present with gender nuances, the general software engineering language issue being well-documented [52]. We suggest that the software engineering community, to promote and sustain its impact and reach, should act to address the present gender distribution issue. As explored in the analysis, employers have an obligation to hire based on suitability for the position and not gender or any other arbitrary demographic. Furthermore, companies have the responsibility to examine and eliminate any biases that may exist within their hiring process to the best of their ability. Our research concludes that, in general, one of the major reasons for the shortage of female software engineers arises from the personal choice of women, whose dominant interests would appear to exist outside of the computing field. However, significant additional research is required in order to better understand the reasons for the software engineering gender distribution disparity, not least because gender disparity raises significant business performance and employee satisfaction concerns.

Software development has been shown to be a complex undertaking [53] that must address many diverse environments and settings [54–57]. This being the case, there would appear to be clear advantages to incorporating balanced and varied problem-solving capabilities in software development settings, and therefore having an under-represented female population might be disadvantaging software firms. We have furthermore seen that there are certain knowledge sharing and retention concerns in software development, especially in Open Source Software project contexts [58, 59], a resolution to which might benefit from the softer human communication skills which females may be more disposed to than their male colleagues.

Our research raises some interesting challenges for the software engineering field. If women tend to opt out of software engineering primarily because they determine it is not of interest to them, then what constructs and approaches can the community elaborate to encourage more females into our business? Doing so should not just be motivated by shallow attempts to merely balance the gender books, but rather out of a realization that without such balance, software companies suffer in many ways. Their potential talent pool is significantly reduced, their capacity to problem solve in diverse ways is diminished, and their very social structures digress from the general population. Software engineering encompasses many perspectives: it is creative, it is also social (perhaps more so since the advent of agile software development), and it provides for relatively well-paid careers in many jurisdictions. It therefore seems that there should be lots of interesting opportunity for females to be equally represented in this industry. The challenge to the industry is to position itself to be of greater interest to females, and this seems to be a challenge that has not been seriously addressed up to this point. Perhaps our methodologies need to change or perhaps the social values of software companies need to be reimagined. Whatever the case, time should be taken to genuinely and radically rethink this space: the software industry needs to find ways to improve its gender balance for the current situation will not magically resolve itself.

**Acknowledgement.** This work was supported, in part, by Science Foundation Ireland grant 13/RC/2094 to Lero - the Irish Software Research Centre (www.lero.ie).

## References

1. Hilton, T., Berglund, G.: Sex differences in mathematics achievement: a longitudinal study. J. Educ. Res. **67**(5), 231–237 (1974)
2. Lippa, R.A.: Gender differences in personality and interests: when, where, and why? Soc. Pers. Psychol. Compass **4**(11), 1098–1110 (2010)
3. Gurer, D., Camp, T.: An ACM-W literature review on women in computing. ACM SIGCSE Bull. **43**(2), 121–127 (2002)
4. Gallagher, A.M., De Lisi, R., Holst, P.C., McGillicuddy-De Lisi, A.V., Morely, M., Calahan, C.: Gender differences in advanced mathematical problem solving. J. Exp. Child Psychol. **75**(3), 165–190 (2000)
5. Clarke, P., O'Connor, R.V.: Changing situational contexts present a constant challenge to software developers. In: O'Connor, R., Umay Akkaya, M., Kemaneci, K., Yilmaz, M., Poth, A., Messnarz, R. (eds.) Systems, Software and Services Process Improvement. CCIS, vol. 543, pp. 100–111. Springer, Cham (2015). https://doi.org/10.1007/978-3-319-24647-5_9
6. Benbow, C., Stanley, J.: Sex differences in mathematical ability: fact or artifact? Science **210** (4475), 1262–1264 (1980)
7. Stereotype threat and the software industry gender gap. https://spin.atomicobject.com/2012/08/01/women-and-the-software-industry-the-truth-about-stereotypes-retention-and-the-gender-gap/. Accessed 04 Mar 2019
8. Atan, H.: Computers in distance education: gender differences in self-perceived computer competencies. J. Educ. Media **27**(3), 123 (2002)
9. Shotick, J., Stephens, P.R.: Gender inequities of self-efficacy on task-specific computer applications in business. J. Educ. Bus. **81**(5), 269–273 (2006)
10. Why does India have a higher percentage of women in tech than the UK? https://www.computerweekly.com/news/252437742/Why-does-India-have-a-higher-percentage-of-women-in-tech-than-the-UK. Accessed 28 Feb 2019
11. 2016 SAT test results confirm pattern that's persisted for 50 years - high school boys are better at math than girls. http://www.aei.org/publication/2016-sat-test-results-confirm-pattern-thats-persisted-for-45-years-high-school-boys-are-better-at-math-than-girls/. Accessed 20 Feb 2019
12. State examinations statistics. https://www.examinations.ie/statistics/?l=en&mc=st&sc=r15. Accessed 28 Feb 2019
13. Women in computer science. https://www.computerscience.org/resources/women-in-computer-science/. Accessed 25 Feb 2019
14. Technology skills 2022 Ireland's third ICT skills action plan. https://www.education.ie/en/Publications/Policy-Reports/technology-skills-2022.pdf. Accessed 06 Mar 2019
15. Stoet, G., Geary, D.C.: The gender-equality paradox in science, technology, engineering, and mathematics education. Psychol. Sci. **29**(4), 581–593 (2018)
16. Goldin, C., Katz, L.F.: The power of the pill: oral contraceptives and women's career and marriage decisions. J. Polit. Econ. **110**, 730–770 (2000)
17. Tenenbaum, H.R.: You'd be good at that: gender patterns in parent-child talk about courses. Soc. Dev. **18**, 447–463 (2009)
18. Gürer, D.: Women in computing history. ACM SIGCSE Bull. **34**(2), 116–120 (2002)
19. Frenkel, A.M.: Women and computing. Commun. ACM **33**(11), 34–46 (1990)
20. Whitecraft, M.A., Williams, W.M.: Making Software. O'Reilly Media, Surrey (2010)
21. Sáinz, M., Eccles, J.: Self-concept of computer and math ability: Gender implications across time and within ICT studies. J. Vocat. Behav. **80**(2), 486–499 (2012)

22. Morse, T.E.: Ensuring equality of educational opportunity in the digital age. Sage J. **36**(3), 266–279 (2004)
23. Jordan peterson interview. https://www.youtube.com/watch?v=yZYQpge1W5s. Accessed 01 Mar 2019
24. Women in wartime: the rise of the female public servant. https://www.theguardian.com/public-leaders-network/2014/nov/08/world-war-women-workplace-public-services. Accessed 02 Mar 2019
25. Perry, D.G., Adam, J., White, A.J., Perry, L.C.: Does early sex typing result from children's attempts to match their behavior to sex role stereotypes? Child Dev. **55**(6), 2114–2121 (1984)
26. Women in computer sciences: closing the gender gap in higher education. https://www.cs.cmu.edu/afs/cs/project/gendergap/www/. Accessed 06 Mar 2019
27. Women and IT by the numbers. http://www.ncwit.org/sites/default/files/resources/2012bythenumbers_web.pdf. Accessed 04 Mar 2019
28. Beede, D.N., Julian, T.A., Langdon, D., McKittrick, G., Khan, B., Doms, M.E.: Women in STEM: a gender gap to innovation. Economics and Statistics Administration Issue Brief No. 04-11 (2011)
29. The first 1940s coders were women–so how did tech bros take over? https://www.history.com/news/coding-used-to-be-a-womans-job-so-it-was-paid-less-and-undervalued. Accessed 27 Feb 2019
30. McKinsey report. https://assets.mckinsey.com/~/media/857F440109AA4D13A54D9C496D86ED58.ashx. Accessed 20 Feb 2019
31. Creating cultures where all engineers thrive. https://www.raeng.org.uk/publications/reports/creating-cultures-where-all-engineers-thrive. Accessed 21 Feb 2019
32. Delivering through diversity. https://www.mckinsey.com/~/media/mckinsey/business%20functions/organization/our%20insights/delivering%20through%20diversity/delivering-through-diversity_full-report.ashx. Accessed 20 Feb 2019
33. Light, J.S.: When computers were women. Technol. Cult. **40**(3), 455–483 (1999)
34. Cardia, E.: Household Technology: Was it the Engine of Liberation? 2nd edn. Society for Economic Dynamics (2008)
35. Lennan, W.: Labour Force Australia 1978-95 (6204.0). Australian Government Publishing Service, Canberra (1996)
36. Teague, G.J.: Women in computing: what brings them to it, what keeps them in it? GATES **5**(1), 45–59 (2000)
37. Raghuram, P.: Migrant women in male-dominated sectors of the labour market: a research agenda. Popul. Space Place **14**, 43–57 (2008)
38. Prescott, J., Bogg, J.: Segregation in a male-dominated industry: women working in the computer games industry. Int. J. Gender Sci. Technol. **3**(1), 206–227 (2011)
39. The Computer Girls: 1967 Cosmo article highlights women in technology. https://www.siliconrepublic.com/people/women-in-technology-the-computer-girls-cosmopolitan. Accessed 03 Mar 2019
40. Irish IT profile (2018). https://www.ics.ie/news/Irish_IT_Profile_2018. Accessed 04 Mar 2019
41. Medel, P., Pournaghshband, V.: Eliminating gender bias in computer science education materials. In: ACM 2017, pp. 411–416 (2017)
42. Smyth, F.L., Nosek, B.A.: On the gender–science stereotypes held by scientists: explicit accord with gender-ratios, implicit accord with scientific identity. Front. Psychol. **6**, 415 (2015)
43. Verbick, T.: Woman, technology, and gender bias. J. Comput. Sci. Coll. **17**(3), 240–250 (2002)

44. Wang, M.T., Degol, J.L.: Gender gap in science, technology, engineering, and mathematics (STEM): current knowledge, implications for practice, policy, and future directions. Educ. Psychol. Rev. **29**(1), 119–140 (2017)
45. Othman, M., Latih, R.: Women in computer science: No shortage here! Commun. ACM **49** (3), 111–114 (2006)
46. The story of lena, the famous test image. http://visionexperiments.blogspot.com/2010/06/story-of-lenna-famous-test-image.html. Accessed 04 Mar 2019
47. Moradi, B., Huang, Y.P.: Objectification theory and psychology of women: a decade of advances and future directions. Psychol. Women Q. **32**(4), 377–398 (2008)
48. The truth about sex differences. https://www.psychologytoday.com/us/articles/201711/the-truth-about-sex-differences. Accessed 25 Feb 2019
49. The more gender equality, the fewer women in STEM. https://www.theatlantic.com/science/archive/2018/02/the-more-gender-equality-the-fewer-women-in-stem/553592/. Accessed 27 Feb 2019
50. Clarke, P., O'Connor, R.V., Leavy, B., Yilmaz, M.: Exploring the relationship between software process adaptive capability and organisational performance. IEEE Trans. Softw. Eng. **41**(12), 1169–1183 (2015)
51. Sauberer, G., Riel, A., Messnarz, R.: Diversity and PERMA-nent positive leadership to benefit from industry 4.0 and kondratieff 6.0. In: Stolfa, J., Stolfa, S., O'Connor, R.V., Messnarz, R. (eds.) EuroSPI 2017. CCIS, vol. 748, pp. 642–652. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-64218-5_53
52. Clarke, P.M., et al.: Refactoring software development process terminology through the use of ontology. In: Kreiner, C., O'Connor, R.V., Poth, A., Messnarz, R. (eds.) EuroSPI 2016. CCIS, vol. 633, pp. 47–57. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-44817-6_4
53. Clarke, P., O'Connor, R.V., Leavy, B.: A complexity theory viewpoint on the software development process and situational context. In: Proceedings of the International Conference on Software and Systems Process (ICSSP), Co-Located with the International Conference on Software Engineering (ICSE), pp. 86–90 (2016). https://doi.org/10.1145/2904354.2904369
54. Clarke, P., O'Connor, R.V.: The situational factors that affect the software development process: towards a comprehensive reference framework. Inf. Softw. Technol. **54**(5), 433–447 (2012)
55. Nevalainen, R., Clarke, P., McCaffery, F., O'Connor, R.V., Varkoi, T.: Situational factors in safety critical software development. In: Kreiner, C., O'Connor, R.V., Poth, A., Messnarz, R. (eds.) EuroSPI 2016. CCIS, vol. 633, pp. 132–147. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-44817-6_11
56. Marks, G., O'Connor, R.V., Clarke, P.M.: The impact of situational context on the software development process – a case study of a highly innovative start-up organization. In: Mas, A., Mesquida, A., O'Connor, R.V., Rout, T., Dorling, A. (eds.) SPICE 2017. CCIS, vol. 770, pp. 455–466. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-67383-7_33
57. Clarke, P.M., et al.: Exploring software process variation arising from differences in situational context. In: Stolfa, J., Stolfa, S., O'Connor, R.V., Messnarz, R. (eds.) EuroSPI 2017. CCIS, vol. 748, pp. 29–42. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-64218-5_3
58. Rashid, M., Clarke, P., O'Connor, R.V.: A systematic examination of knowledge loss in open source software projects. Int. J. Inf. Manag. (IJIM) **46**, 104–123 (2019)
59. Rashid, M., Clarke, P.M., O'Connor, R.V.: Exploring knowledge loss in open source software (OSS) projects. In: Mas, A., Mesquida, A., O'Connor, R.V., Rout, T., Dorling, A. (eds.) SPICE 2017. CCIS, vol. 770, pp. 481–495. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-67383-7_35