Why Don't More Young Women Study Computing?

A Working Paper Investigating the Low Participation of Girls taking Computing in Northern Ireland Schools

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Contents

Executive Summary

As studies from government and industry consistently make clear, the global workforce of the future will benefit from greater diversity and inclusion. At present, one of the largest skills gaps in the labour market is in the field of computing and digital technology, with the industry in the United Kingdom (UK) growing 32% faster than the economy overall (Tech Nation, 2018). For this gap to be filled now and in the future, more workers with advanced computer-related skills are and will be needed. Thus, for educators in Northern Ireland (NI), the UK, and around the globe, equipping students with these particular skills presents one of the most significant educational challenges of present times.

Acknowledging the need for greater participation in computing at schools, alongside heightening levels of diversity and inclusion, has led to this CCEA research paper. A significant gender disparity exists in computing at schools in NI, with considerably more males currently pursuing computing-related subjects at both GCSE and A Level. This CCEA research paper therefore examines the presently low levels of participation of female students in computing-related subjects in NI, attempting to (i) understand why fewer young women study these subjects, and (ii) establish various ways in which their participation might be encouraged and thus their overall entry numbers at school increased.

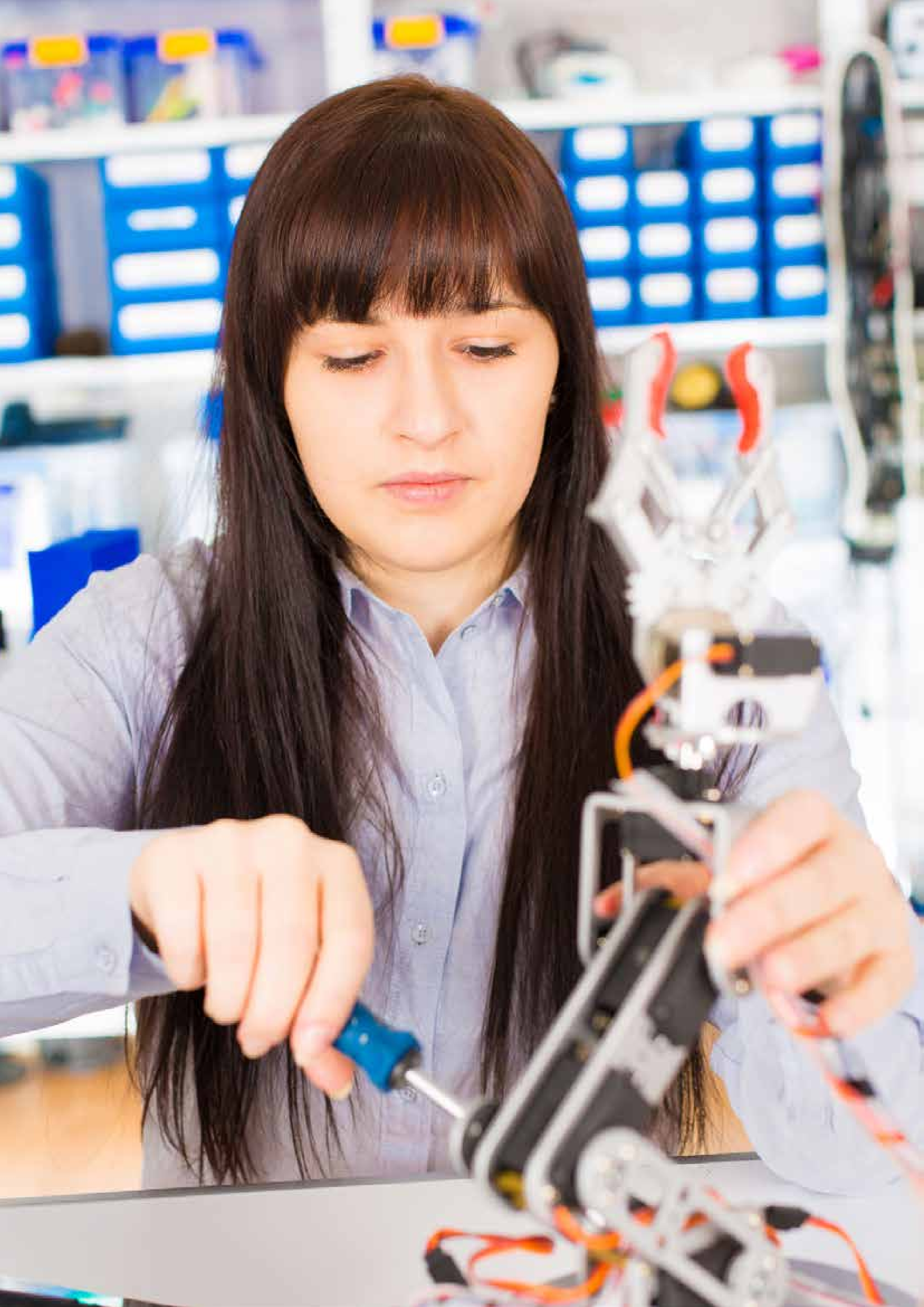
It is the contention of this research paper that the total entry numbers of females into computing-related subjects in NI at GCSE and A Level is much lower than that of males and, importantly, that the primary causes of this differential stem from cultural stereotyping. Specifically, it is the stereotyping of computing as a male-dominated activity that dissuades young women from feeling a sense of belonging in the computing environment; that, as a result, causes females' increased computer anxiety and lower self-efficacy. These feelings are worsened by the negative experiences with computers young females often have at home, at school, in popular culture, and when faced with computing as a career. These factors establish significant barriers to female participation in computing at school, therefore, reflected by the low level of female entry across GCSE and A Level in NI.

With these barriers outlined, this CCEA research paper discusses a range of potential remedies to low female participation in computing at schools, all considered in light of the need to cultivate a positive sense of belonging for females within the computing environment. These remedies include: the need for further research into the NI educational context; integration of positive female role models into schooling programmes; changes to the computing teaching environment; the integrated use of Inclusive ICTs; and the promotion of computing as a career choice for females.

Although the success of these remedies is likely to be seen only in the long-term, it is hoped that this paper incites further discussion and motivates policy-makers towards closing the gender divide in computing at schools in NI.

1

Introduction



1 Introduction

It is increasingly clear that success in business is enhanced by diversity in the workplace. Understanding that inclusivity and diversity are essential for success led CCEA to question whether there was gender diversity in qualification choices in schools. There are a number of qualifications with gender differences in entries, but one area stood out as worth further investigation. This CCEA research paper therefore investigates the presently low levels of participation by female students in computing-related subjects in Northern Ireland (NI).

Over the past decade, computing and digital technology has become 'a truly global industry' (Aspray, et al, 2006: 4), rapidly increasing the demand for workers in all countries who have high levels of training in the science, technology, engineering, and mathematics (STEM) fields and, in particular, computer-related fields. In the face of intensifying global competition, policy makers, scholars and educators all claim that preparation in computer-related subjects is vital to the economic health of all nations, and NI is no exception. Careers requiring advanced computer skills are currently among the fastest growing occupations, with the UK tech industry growing 4.5% between 2016 and 2017, compared to a national GDP growth of only 1.7% (Flinders, 2018). Recent estimates value the UK digital tech industry at £185billion (Tech Nation, 2018), while the 'Big 5' tech giants (Apple, Alphabet, Amazon, Facebook, Microsoft) are worth a combined $3trillion worldwide.

According to recent analysis by Tech City UK and innovation charity Nesta, the UK's digital tech industries has grown 32% faster than the rest of the UK economy in recent years (Tech Nation, 2018). A report in 2015 by O2 said that 2 million digital skilled workers will be needed by 2020 in order to fulfil the UK's digital potential (O2 Business, 2015). This highlights the demand for highly skilled workers within the fields of computing and digital technology; something reflected in the CBI/Pearson's 2018 report, which stated that employers rank digital skills decidedly highly when considering recruitment to their future workforce:

> *'Reflecting the growing importance of technology in almost every aspect of working life, over a third of respondents cite digital and IT skills as one of the three most important factors when recruiting school and college leavers'*
> (CBI/Pearson, 2018: 24).

Job prospects in the computing sector are flourishing in NI and there continues to be a growing demand for more workers across the industry. Yet, the present rates of employment within the sector are far from equal. The average number of females in technical fields is notably below the average number of males, particularly in Western countries (Lamborelle & Fernandez, 2016). In the UK tech sector, only 17% of employees are female (Women in Tech, 2019). With the demand for computing professionals increasing, this disparity will have a dramatic impact on cultural, industrial and economic realities around the world. This research paper examines the educational, social and cultural factors that may influence female involvement and suggests strategies for increasing female participation in computing.

The 'Digital Divide': Low Participation of Female Students in Computing

The low rate of female employment within the computing and digital technology sectors can be accounted for, to a significant degree, by the lack of females choosing to pursue computing-related subjects at school and University (Lehman et al. 2017). In NI, the number of female students studying computing at A Level is extremely low, especially when compared to males (e.g., 50 females and 314 males in 2018). With this disparity, however, NI is not alone; and is instead symptomatic of a larger trend across the rest of the UK, and the West more generally. In the UK, the latest figures published by the Department for Education stated that only 0.4% of females taking A Levels chose computer science in 2017, compared with 4.5% of male students. At university level, computer science has been one of the fastest growing teaching areas over the past five years - yet, of the 107,250 students that entered computer science courses across UK institutions in 2017/18, only 18,880 (=17%) were female (HESA, 2018).

The marked differential in the number of females studying computer-related subjects compared to males has, quite naturally, spurred a significant amount of scholarly work on the reasons underlying the continuing 'digital divide' (for examples, see Abbatt, 2012; Hilbert, 2011; Joiner, et al. 2015; Lin, 2016; Vitores & Gil-Juárez, 2016). Importantly, however, it is not a difference in skill level with computers that separates males from females. Empirical studies consistently show that females are equally adept as males when it comes to operating computers and computerised programming. It is crucial to point this out, as the temptation to lay the blame for female non-participation in computing subjects with a lack of skill is enticing – particularly when, as discussed later in this paper, existent cultural stereotyping dictates this as a conceivable explanation for the difference. Instead, as argued by Clegg and Trayhurn (2000), it is important to 'ask what is wrong with computing rather than what is wrong with women'. In other words, what are the reasons underlying the low levels of female participation in computing subjects given the potential capabilities of females when using computers – for education, work, and leisure – are no different to males (NCWIT, 2012).

It is the contention of this paper that the major barriers to female participation in computing stem from cultural stereotypes that portray typical computing participants as male. Emanated from across popular culture, this stereotype creates a multifaceted stereotype threat to females (i) to perform overly well, and (ii) to their self-image as feminine teenagers. This threat may manifest in producing a feeling within females that they do not belong in the computer lab, as a student or a worker. Females, in other words, lack a sense of belonging when it comes to studying computing. According to Blaney & Stout, a 'sense of belonging is defined as the subjective feeling of fitting in and being included as a valued and legitimate member of an academic discipline, and is a known predictor of academic persistence and achievement' (Blaney & Stout, 2017) This lack of a sense of belonging precludes females from wanting to study computing at school or pursue it as a career. Thus, for this situation to be remedied, ways must be found to cultivate this sense of belonging within the computer classroom, thereby overcoming some of the major barriers to female participation established by pre-existent stereotyping.

STEM - A Gendered Context

It is crucial, when considering the digital divide in education, to acknowledge that computing subjects do not exist in isolation. Instead, they fit within the broader subject area composed of science, technology, engineering, and mathematics, known as STEM. Within STEM, a gender gap exists more generally, with females consistently choosing to participate in fewer STEM subjects as they progress through their school lives. This lack of participation results in notable achievement gaps between males and females, with males achieving more success by virtue of their greater levels of participation alone. The negative consequences of this achievement gap were reflected upon by World Economic Forum in 2011:

> *These achievement gaps [in STEM] have been a matter of great concern among social scientists, policy makers, and the general public. Given the projected shortage of an educated workforce in the near future, eliminating factors responsible for the achievement gap can be a key for future economic growth*
> (World Economic Forum 2011).

Thus, for international policy makers, tackling the achievement gap brought about by a lack of female participation in STEM and, in particular, computing, is of high priority; a critical objective if the demands of the future global workforce are to be met.

In NI, gender differences in STEM are evident in post-primary students at GCSE and A Level (CCEA, 2018), and the situation is similar for the whole of the UK (Tsan, et al. 2016). According to a recent UK government report, when asked about potential subject choices for A Level, females are much less likely to pursue STEM, with engineering (females 14%, males 86%), computing (females 15%, males 85%) and physics (females 22%, males 78%) particularly unpopular choices among female students. In response to the report, UK School Standards Minister Nick Gibb stated the ongoing need to tackle the differential by dispelling existent misconceptions about STEM held by some students:

> *"This research, however, shows that certain misconceptions are still prevalent, and we all have a part to play, including parents and teachers, to dispel misconceptions about STEM subjects and help encourage our scientists of future generations."*
> (Department for Education, 2019)

Contemplating and challenging these misconceptions, specifically those concerning females' participation in computing, is a crucial focus of this paper; a focus that, for the CBI/Pearson, might help lead to greater 'exposure to the hands-on application of STEM knowledge [that] can [in turn] help foster greater appreciation of its importance' for the employees of the future (CBI/Pearson, 2018: 29).

Outline of Working Paper

It is with this context in mind that this paper operates to recall and examine the reasons underlying the low participation of females in computing-related subjects in NI, before suggesting potential ways in which female participation might be increased in the future.

The paper begins with a section outlining the available data on female participation in computing-related subjects at GCSE and A Level in NI. These data evidence the notably low levels of female participation in computing when compared to their male counterparts. Data on other STEM subjects are also supplied to serve as comparators, demonstrating that low female participation levels are widespread across STEM and not confined to computing alone.

The following section addresses the relevant academic literature and media output on female participation in computing in order to identify the possible reasons underlying the low levels of female engagement. It is argued that stereotyping and, in particular, stereotype threat are pejoratively responsible for low participation levels among females, with their consequences including the development of ‘computer anxiety’ and feelings of low self-efficacy among female student populations. These anxieties emergent from stereotyping prevent females from developing a sense of belonging in the computing environment, which in turn restricts their overall participation in the subject at GCSE and A Level.

The final substantive section queries what kinds of remedies can be sought to improve female participation in computing by looking at ways of cultivating a sense of belonging within the computer lab for females. These methods include the need for further research in the NI context, tackling stereotyping via the promotion of positive female role models, alterations to the existing teaching environment (teaching methods and curriculum), the integration of Inclusive ICTs in schools, and through the promotion of computing careers awareness among females. These measures, it is concluded, are the most effective ways of nurturing a sense of belonging for females within computing and by virtue, increasing their participation within the subject at schools.

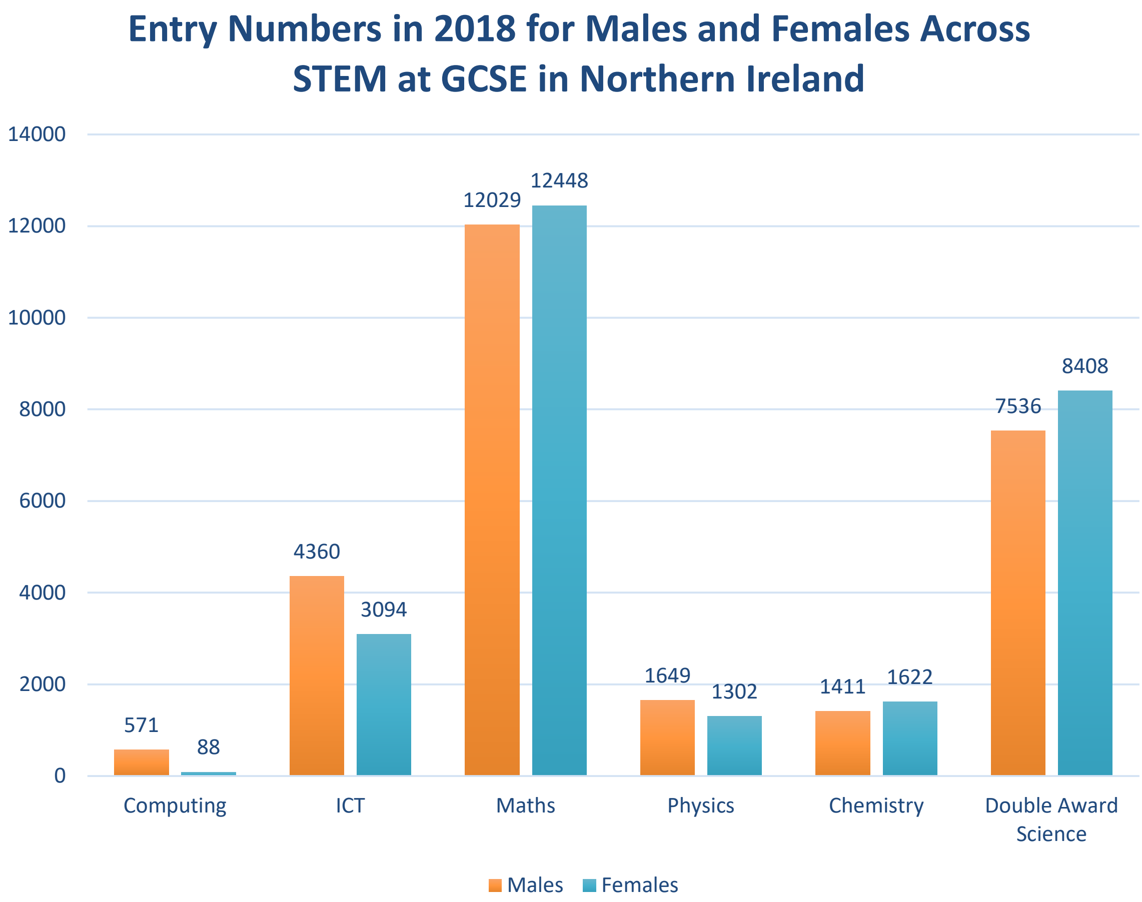
2

Female Participation in Computing-related Subjects in NI

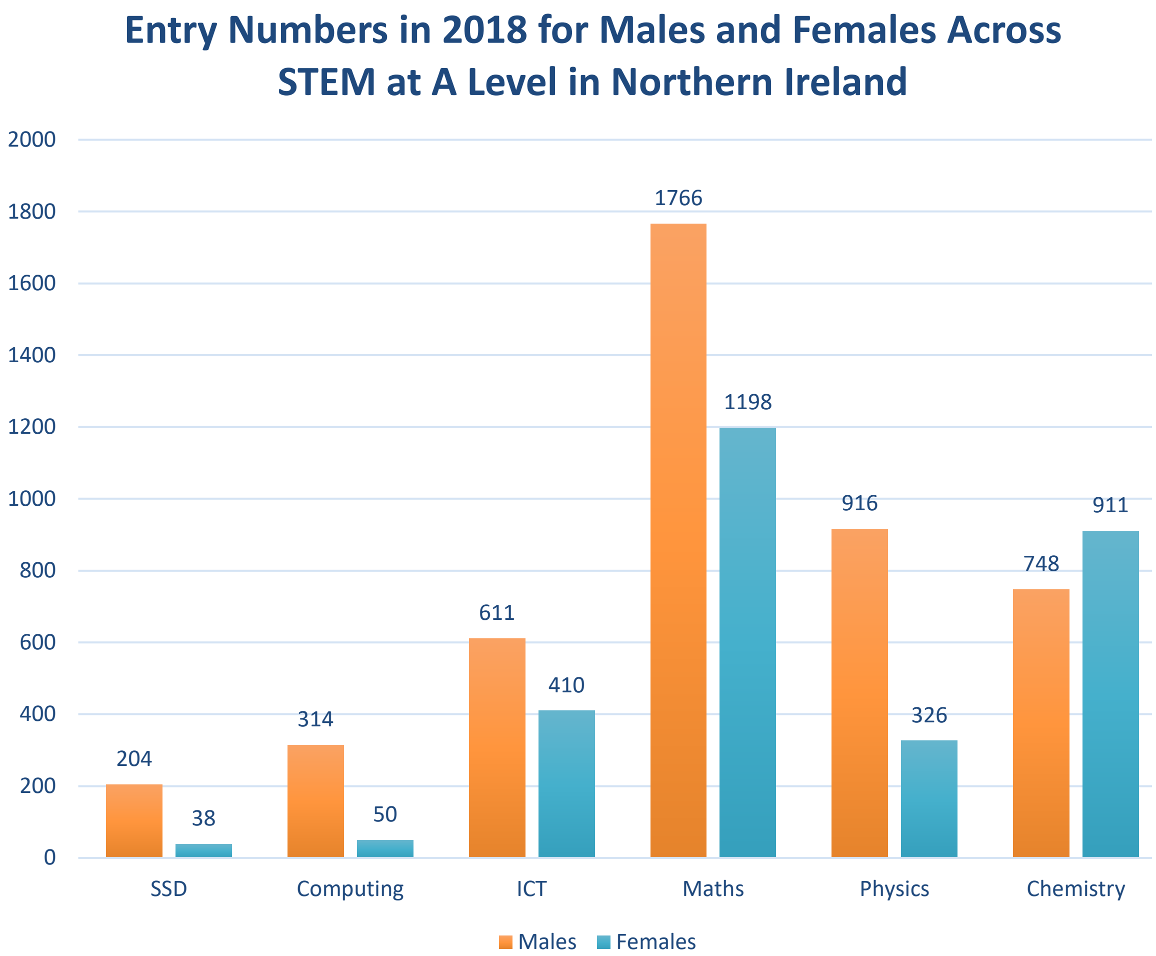
2 Female Participation in Computing-related Subjects in NI

To understand the issues around female participation in computing-related subjects, it is important to identify current trends at GCSE and A Level in NI. The total entry for computing-related subjects is divided across several different specifications, including ICT and Computing at GCSE, and Software Systems Development, Computing and ICT at A Level. The entry for these specifications is included alongside the entries for other STEM subjects for the purposes of comparison. In each case, the entry for an individual specification is split according to gender.

Entry Numbers for GSCE and A Level in 2018



Source: JCQ. Available at: https://www.jcq.org.uk/



Source: JCQ. Available at: https://www.jcq.org.uk/

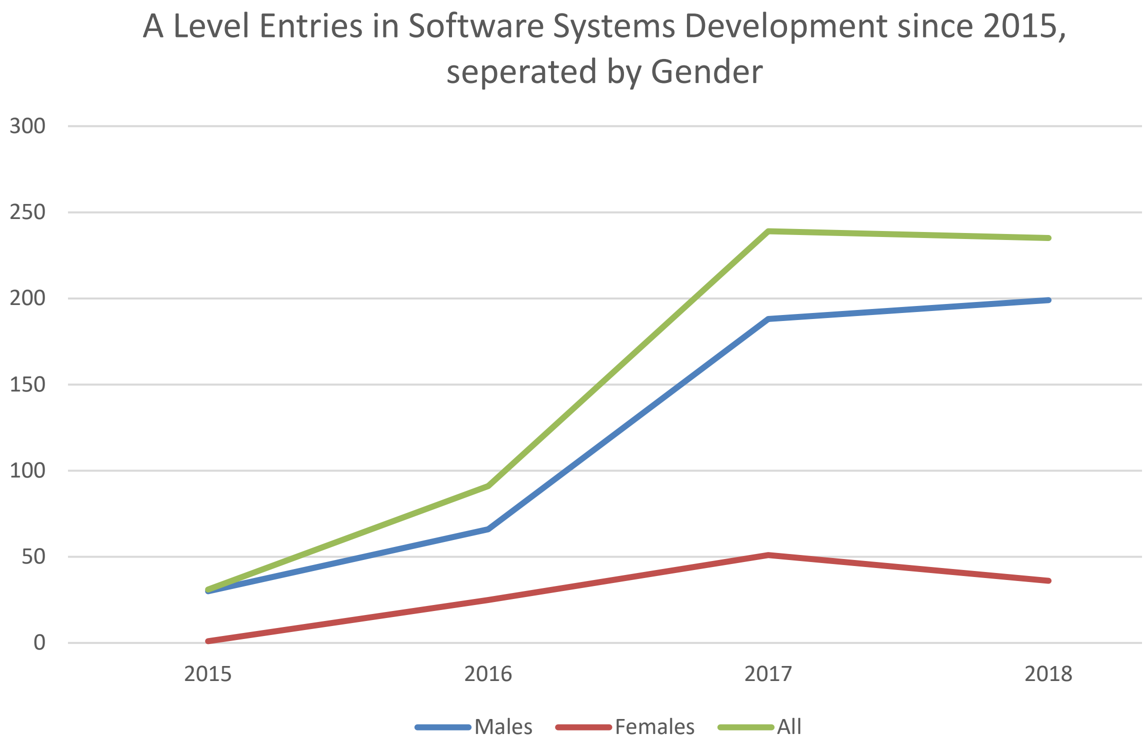
A number of conclusions can be derived from these entry figures from 2018:

a) Of the computing-related subjects at GCSE and A Level, ICT is the most popular with both genders by a considerable distance. There were over 7300 total entries for GCSE ICT and over 1000 A Level ICT. This compares to less than 700 entries for Computing at GCSE and around 600 entries across SSD and Computing at A Level.

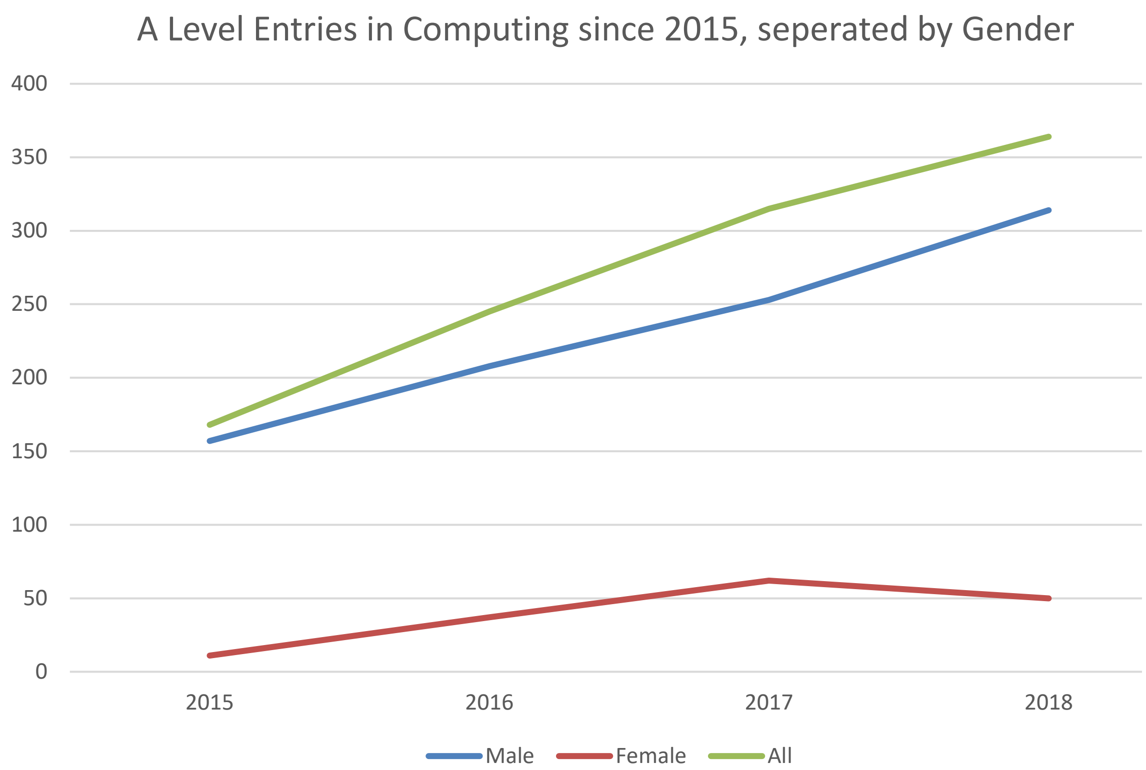
b) In all specification of computing-related subjects at GCSE and A Level, male entries outnumber female entries. This differential is the starkest in what are considered the more complex specifications (e.g. Computing and SSD) that directly involve computing tasks such as programming and coding. Although more males than females participated in ICT at both GCSE and A Level, the differentials were less grave (with females amounting to around two-thirds the total number of males).

c) Fewer students are participating in computing-related subjects than in other STEM subjects.

Participation trends in Computing-related subjects at A Level in NI since 2015



Source: JCQ. Available at: https://www.jcq.org.uk/



Source: JCQ. Available at: https://www.jcq.org.uk/

The Irish News reported in 2018 that the number of jobs for IT professionals in Northern Ireland had risen by over 40 per cent since 2017 according to figures released by NIJobs.com. Looking at data for A Level entries in computing-related subjects in NI for the four years leading up to this time clearly demonstrates a notable gender differential persistent over the past four years. A number of conclusions can be drawn:

a) Overall participation in computing-related subjects at A Level has increased dramatically, with approximately 600 students in 2018 (across both Computing and SSD) compared to approximately 200 in 2015.

b) The overall trend indicates a year-on-year increase in participation, with the only slight anomaly being a drop in 2018 in SSD.

c) The number of males participating in both SSD and Computing has far outweighed the number of females every year, with little sign that the gap is closing.

Summary from the Entry Data

Overall, this entry data reveals that, within NI, a considerable differential in participation exists between the genders. Although more students than ever are taking computer-related subjects at GCSE and A Level the number of males far outweighs the number of females in every specification. This trend has been the case in recent times but also for the last ten years and shows little sign of changing. The increase in computing/digital A Level students and the economic demand for graduates only highlights the gender gap in this area further.

3

Barriers to Female Participation in Computing

3 Barriers to Female Participation in Computing

This section consists of a comprehensive review of the relevant contemporary academic literature on female participation in computing-related subjects at school and university. The aim of this review is to identify, and extrapolate upon, the possible reasons underlying the low uptake of computing courses by female students in NI. As McGowan and colleagues (2017) report, '[t]here is a substantial body of research into the computing gender divide which suggests that young women in secondary level education display a more negative attitude towards computing than their male counterparts' (see Sáinz, 2016). It is this negative attitude, then, which many see as responsible for fewer females enrolling in computing courses later in their school careers (Baser, 2007) – especially given, as Roger and Duffield (2000) suggest, the barriers to females' participation in computing are established early in post-primary, with the effects of these barriers manifested in enrolment numbers in later years. This section investigates what these barriers are and how they are formed by beginning with two central themes in the literature: stereotyping and its effect, 'stereotype threat'. As forwarded by Stout and Camp (2014), when computing is viewed as a cultural and economic field, females are a disadvantaged group within it. They have to contend with negative stereotypes about their ability in computing and, crucially, a chronic sense that they do not 'belong' (Stout and Camp, 2014). By initially investigating how the stereotyping of females with computing comes about this section can explore the barriers to female participation that emerge from it – including 'computer anxiety' and the resultant low self-efficacy that, together, prevent females from developing a sense of belonging within the computing environment. Only by comprehending how this lack of belonging is established, can remedies for greater female participation in computing be sought later.

Stereotypes

The most popular starting point for studies investigating the low participation of females in the computing field is the argument that many of the barriers preventing greater female participation emerge as a result of stereotyping (Siek et al. 2006; Sáinz, 2011 Beyer, 2014; Master, et al. 2016). The particular stereotype of concern is 'the image…of computer scientists and people in computer science as awkward, nerdy males who lack interpersonal skills and are obsessed with technology' (Vitores & Gil-Juárez, 2016). This, these studies claim, presents the computer lab, and computing in general, as a male-orientated domain consisting of anti-social 'nerds, geeks, or hackers'; a realm within which females do not belong (Beyer, 2014: 155; Cohoon & Asprey, 2006; Cheryan & Plaut, 2013). Conceptually, stereotyping relies on the theoretical understanding that all identities are socially constructed, emergent through the complex interplay of language and discourse between and within dominant cultural paradigms (Fiske et al. 2002). Fundamentally, stereotypes are shared cultural beliefs about a person's character or ability derived from parallel beliefs about a broader societal group. They are not necessarily derisory but often are, resulting in forms of discrimination or prejudice against individuals and groups; typically on the basis of some aspect of their personal or collective identity (e.g., gender, skin colour, age, nationality, etc.). Significant to the play of stereotyping is presumptive extrapolation – specially, the extrapolation of an individual's personality and/or life-style on the basis of a singular characteristic. For females and computing, it is their gender that is extrapolated, with their supposed lack of experience/skill derived on the basis of their being female (or, rather, not male) alone (e.g. *"They're a girl so they can't be good at using computers"*). Other attributes that have been ascribed to females in the past, despite the existence of opposing evidence, include being less talented at mathematics and technical sciences than males (Nelson, 2009), desiring more domestically- orientated careers than males (Abele & Wojciszke, 2007), and being less equipped for complex working environments than males (Ridgeway, 2001). When considered together, these stereotypical traits mean 'the predominately masculine characteristics conjured by stereotypical images of computer scientists may deter females from becoming interested in the field' (Cheryan, et al. 2013: 58).

When it comes to explaining low female participation in computing, it is the impact of stereotyping creating barriers to participation that is significant, affecting the choices of females to study or work with computers (Hill, 2015). In their seminal study, Steele and Aronson observe that the impact of a stereotype is profoundly limiting:

> *'[T]he existence of such a stereotype means that anything ones does or any one of one's own features that conform to it make the stereotype more plausible as a self-characterisation in the eyes of others, and perhaps even one's own eyes. We call this predicament stereotype threat...'*
> (Steele and Aronson, 1995: 797).

'Stereotype threat' is the label given to the restricting effect of a stereotype and it is 'known - first and foremost - as a factor that inhibits stereotyped individuals [from performing] up to their full ability' – often leading to the individual's eventual 'dis-identification from the stereotyped domain' entirely (Appel & Kronberger, 2012; Kaye, 2016). In other words, stereotype threat manifests as a set of limitations placed upon the target group, restricting the groups' performance, causing them to further disassociate themselves from the cultural context within which they are stereotyped (Nguyen & Ryan, 2008). It is in this way that a stereotype (e.g. that computing is a male-domain) creates a substantial and long-lasting barrier to a groups' (e.g. females) future uptake or success.

According to Spencer and colleagues, '[people] experience stereotype threat when they are at risk of being judged or treated in light of a negative stereotype about one of their social identities. The extra pressure to avoid confirming the stereotype has been shown to undermine performance in negatively stereotyped domains' (Spencer, et al. 2016: 430). As they argue, stereotype threat manifests in two important ways: underperformance due to extra pressure; and underperformance due to threats to self-integrity and belonging. Both of these need to be considered in line with the learning environment within schools and the societal aspects of young female students' lives (i.e. the pressures of conformity experienced frequently by teenagers) if the stereotype threat to females in computing is to be fully understood.

First, underperformance due to extra pressure. Persons experiencing stereotype threat are motivated to contest or disconfirm negative stereotypes that target their social identity (Kray & Shirako, 2011). This motivation to contest represents a pressure to succeed that non-stereotyped individuals do not face and thus disadvantages the stereotyped group. This pressure can manifest in a way that encourages the stereotyped individual to avoid the challenge completely, thereby avoiding the risk of failure. This might explain why female students choose not to enrol in computing given that, with small numbers currently up-taking, the pressure to excel in the field is that much greater. The need to prove oneself when negatively stereotyped would act against the female student, automatically dissuading them from trying. Indeed, such is the depth of this pressure that studies have shown the desire to battle against a stereotype can even impact one's physical wellbeing once a task is undertaken, causing increased stress to the mind and body (Aronson, et al. 2013).

Second, underperformance due to threats to self-integrity and belonging (Cundiff, et al. 2013). On occasion, underperformance, or a lack of participation, may be explained by the actions individuals take to protect their own self-image (Stone, 2002). As noted by many scholars, computer scientists are often viewed as 'single-minded, lacking outside interests, and intelligent but deficient in interpersonal skills'. In essence, they are thought of as 'nerds, geeks, or hackers' (Beyer, 2014: 155. Also Cheryan, et al. 2013). This could explain female students' refusal to take up supposedly 'male' subjects such as computing, as this would prevent others attributing them as 'geeks', thereby helping to protect their existing feminine self-image. This, it can be suggested, is only amplified by the high levels of societal- and peer-pressure felt by females of school-age who, despite perhaps having an erstwhile interest in computing, might choose to act against their self-interest in order to fit in with the crowd (Cohoon & Aspray, 2006; Robnett & Leaper, 2012). As research by Eccles and colleagues (1999) has shown, it is this aspect of stereotype threat which has the most profound bearing on students' decisions regarding subject and course selection while at school or college.

Meta-analytic studies (see, for instance, Walton and Cohen, 2003) have repeatedly shown that individuals perform less well when their stereotype threat is high. As Walton and Cohen point out, the ultimate effect of this is that stereotype threat has the disturbing potential to weaken target individuals' sense of belonging, thereby undermining their motivation and making them more likely to refuse uptake to begin with (Walton and Cohen, 2007).

> *'In professional or academic settings, people whose groups are stereotyped or otherwise stigmatized tend to be uncertain of the quality of their social bonds. For this reason, they are especially sensitive to signs that they do not belong'* (Spencer, et al. 2016: 424).

This goes some way to explain the importance of the learning environment and, in particular, 'a sense of belonging' when considering the participation in computing by female students. What is perceived to be a male-orientated domain (e.g. the computer lab) can, despite the best efforts of the teacher, disincentive female participation through the presence of artefacts considered typically masculine (e.g. computer hardware, technical equipment, tools, etc.) (Woodcock et al. 2012). When already under stereotype threat, female students are likely to be 'especially sensitive' to this environment, thus dissuading them from future participation.

By way of remedying stereotype threat, in their study regarding minority racial groups in corporate settings, Purdie-Vaughns and colleagues (2008) found that such groups felt that stereotype threat was reduced when efforts were made within their work environment to foster their own sense of belonging. Other strategies that have been tried include educating participants, reassuring them that the stereotype is illegitimate or ill-informed, and guiding them to attribute any anxiety to a stereotype as opposed to their own perceived personal deficiencies (Johns, et al. 2005). Educating individuals to contest stereotypes can be achieved in a number of ways, with the promotion of positive role models who stand as cultural symbols against the existing stereotypical image being a prime example. A number of these strategies will feed debates explored later in this paper as, for now, attention must remain on the implications of stereotype threat and the pressures on target groups that it creates.

'Computer Anxiety' – Values and Interests

As a result of stereotype threat, specifically the increased pressure to perform well and thereby disconfirm the stereotype, female students develop what the literature calls 'computer anxiety'. According to Howard and Smith (1986: 1) computer anxiety is defined as 'the fear of impending interaction with a computer that is disproportionate to the actual threat presented by the computer'. This manifests 'when a person feels uncomfortable and anxious when using or being expected to interact with a computer' (Howard and Smith, 1986). Computer anxiety can relate to both a generalised anxiety about the operation of a computer (e.g. turning it on, navigating interfaces, operating hardware), and an application-specific anxiety that emerges when particular types of applications (or computer functions) are tasked (e.g. coding) (Brown, et al. 2004). This explains why, for female students comfortable with routine computer usage (e.g. social networking), advanced complex computing tasks may still be anxiety inducing. The idea of studying computing is, in other words, outside of their comfort zone, with the computer lab not feeling like somewhere they belong.

One way of interpreting females' increased computing anxiety in comparison to males is to consider how the apparent values and interests of females differ from males throughout childhood and adolescence (see Adya & Kaiser, 2005; Bartol & Aspray, 2006; Sáinz & López-Sáez, 2010). Generally, this research suggests that males tend to have a higher baseline positive attitude towards computers than females and, therefore, that they have higher levels of interest and expectation in relation to computer-related studies and computing careers. This difference develops through early childhood when males have more *playful* or *fun* experiences with computers, and thus grow to see them as 'toys' with interesting 'technical' and 'mechanical' aspects. Conversely, females are deemed to view computers more instrumentally – as a 'mere' tool – and are therefore more interested in computers' communication possibilities than their technical aspects (Vitores & Gil-Juárez, 2016). This gender difference in computer-based interests is backed by statistical evidence from a recent OFCOM publication (2018) which confirmed that, in terms of time spent using digital technology, the biggest disparity between the teenage genders was in time spent playing computer games: on average, UK females aged 12-15 spend around 9 hours per week gaming, while males of this age spend over 16 hours. This is not to say that computer gaming makes males more proficient at using computers, of course, or that more gaming for females is an automatic remedy to the disparity (Kelleher & Pausch, 2007). Rather, it is to say that, with more time spent computing, males have a greater opportunity to increase their familiarity with the technical and mechanical aspects of the machines; thereby ultimately lessening their anxiety when confronted with other computer-based interactions in their educational or vocational futures. For males, this heightens the sense of belonging in computing environments that females are seen to lack.

A further difference in interests between females and males that is pointed to by the literature is females' supposed desire for a 'balanced' life involving multiple roles and goals, including career, family, social interactions, hobbies, and so on. This, some argue, conflicts with the stereotypical view of the computer scientist or programmer as a preoccupied loner, obsessed with their machines and with a lack of interest in people (Eccles et al. 1999). Moreover, other studies claim that males and females differ in their personality orientation, with females favouring interpersonal interaction and nurturing, and males favouring isolation and personal drive (Rommes et al. 2007; Zahn-Waxler, 2000). This is reinforced by the multitude of research publications that have consistently found that males do not share female's greater interest in people and, instead, are seen to value material things (Su, et al. 2009). These differences in interests and values are all said to work against females increased participation in computing at school and in their careers. With computers and digital technology deemed a male-domain – somewhere only males belong – females can easily perceive themselves as outcasts.

It is important to note that these arguments concerning the contrasting interests of females in comparison to males, while essential considerations in the debate over female participation in computing, must be handled with care. They are, as feminist critiques point out, overly simplified and potentially damaging generalisations (Valian, 2014; Vitores & Gil-Juárez, 2016). That is to say, with stereotyping playing such a crucial role in preventing females taking up computing, it is imperative not to rely heavily on such stereotypes ourselves as a way of combating the problem. Instead, efforts must be made to understand the effects of stereotyping and the lack of belonging it leads to without oversimplifying and thereby undermining our understanding of females' heterogeneous interests to begin with. It is with this warning in mind, that it is important to focus on the impact of computer anxiety on females - and, as several studies have found, negative attitudes towards computers are positively correlated to a lack of computer experience and, crucially, perceptions of low self-efficacy (Meelissen & Drent, 2008; Sáinz & López-Sáez, 2010).

Computing Self-Efficacy

Much of the research points to the chief consequence of computer anxiety as females' lower 'computing self-efficacy' (Marakas et al. 1998; Meelissen & Drent, 2008). Self-efficacy refers to beliefs about one's aptitude to strategise for and execute steps required for future success, and research has shown that self-efficacy promotes learning performance, retention and motivation (Lin, 2016). It is, in this way, keenly tied to the factors underlying female students' choices over whether to enter computing courses while at school (Correll, 2004). For instance, computer self-efficacy has been found to predict involvement with computers (Compeau, et al. 1999) and intention to study computing courses (Sáinz & Eccles, 2012). Across STEM, females may have low self-efficacy, believing that they do not have natural ability in male-dominated disciplines, particularly Engineering, Chemistry, Mathematics and Computing (Beyer, 2014). Importantly, however, females' self-efficacy is incorrectly low in comparison to their true abilities (Jagacinski, 2013). Rather, it is the fact that such subjects are considered masculine which is critically significant. As research has reliably shown, the more a subject is thought to be suitable for males, the more females lack a sense of belonging, and this lack causes females to possess lower self-efficacy (Correll, 2004). As pointed by Fox, Sonnert & Nikiforova (2011), female directors in engineering programs believed the biggest barrier to greater female representation was lowered computer confidence; meaning that raising the self-efficacy of female students could be the key factor in raising participation levels at schools, Universities and in the workplace.

It is regularly cited that computer self-efficacy is directly related to one's own - positive or negative - experience with computers (Correll, 2004; He & Freeman, 2010), and is compounded by one's existing level of interest in and knowledge of the subject (Schmidt, 2011). This is crucial because, as is well-documented, females encounter computers less regularly at an early age (Varma, 2009), have less programming experience as a consequence (He & Freeman, 2010), and show an interest in computing much later in life than males (Lang, 2010). Amplifying this, research has shown that if females take a computer-related subject at post-primary level they will be more likely to study such subjects at university compared to females who did not study such subjects (McInerney, et al. 2006). Females' low self-efficacy, therefore, should not come as an overt surprise. Rather, as a result of cultural stereotyping and a lack of a sense of belonging, computing self-efficacy among females limits their confidence when faced with the same opportunities to study the subject as are presented to males. Males' high self-efficacy promotes their participation, resulting in the marked gender differential in entry uptake within computing at schools. Despite many of these studies being 10-20 years old, more recent research has not disputed the theories, suggesting that societal change has not impacted on computing self-efficacy.

The difference in computing self-efficacy between males and females is stark. In their seminal study concerning university students, Beyer and colleagues found that males had more confidence in using computers than females even when statistically controlling quantitative ability; in fact, female computer science undergraduate degree participants had less computer confidence than males not doing the subject (Beyer et al. 2003). This is striking because it reveals the high degree to which females' perceived low computing self-efficacy has been internalised. Even females actually participating in computing education were shown to have less confidence in their ability than males not participating. A principal impact of this internalisation of low self-efficacy is, according to Henwood, the exceptionalisation of females who do participate successfully in computing subjects. As Henwood observes, because of the widespread self-belief that females cannot participate in computing effectively, the minority of females that do, see themselves, and are seen by males, as exceptional:

> *'[Women who do computer science are seen as] different from the majority of women, who are thereby rendered incompetent and outsiders in technological culture. [T]he task of changing the outcomes of women's education in computer technologies is more complicated than simply teaching them how to use computers. It is also necessary to change how the women (and the men around them) understand and talk about the presence and competence of women.'*
> (Henwood, 1999: 24-25)

In other words, the computing self-efficacy of females is promoted, not by evidentiary means (e.g. by showing how female students are equally, if not more, successful than males at the subject), but by changing the cultural conversation around computing and education.

The low computing self-efficacy of females, therefore, stemming from stereotyping, a lack of a sense of belonging and computer anxiety, results in large numbers of females opting not to study computing at school. However, as stated above, self-efficacy is fed by one's existent experiences with computers – implying that, to understand low self-efficacy, we must look to the experiences of females with computers in different areas of life: (a) in the classroom; (b) at home; (c) within popular culture; and, (d) as a career prospect.

Existing Experiences of ICT/Computing

(a) Within the Classroom

At post-primary, females outperform males in the majority of subjects at GCSE and A Level. However, this does not contradict the wealth of observations of gendered dynamics in the classroom. For instance, in line with the lack a sense of belonging discussed, the image of a computer scientist as a male ‘geek’ has been constitutive in making the computing classroom a metaphorically ‘chilly climate’ for women (Simon, et al. 2017; Walton, et al. 2015). On the one hand, this ‘chilly climate’ is the result of historical structuring - the prevailing discourse in computing has been configured by social practices which have institutionalised the power of experts, mostly male, to delineate what counts as computing in education (Clegg, 2001; Vitores & Gil-Juárez, 2016). The reproduction of this gendered discourse, fed by cultural stereotyping, is one way of explaining the perpetuation of females’ lower participation in computing at schools (Clegg, 2001). On the other hand, this ‘chilly climate’ for females is a reality constituted by contemporary teaching practices, the gendered nature of social interactions within the classroom, and the structuring of the computing curriculum.

To begin with contemporary teaching practices. Within the literature on the education of females, a recurrent theme indicates that ‘climate’ is a guiding variable in females’ class participation and, in the long run, their educational outcome (Tatum and Schwartz, 2013; Peters, 2013). Dynamic involvement in both the classroom and cross-curricular undertakings has been found to positively influence the educational achievements of female students (Kuh, et al. 2011; Quaye & Harper, 2015). However, a ‘chilly’ atmosphere where there is no sense of belonging can do the reverse: inhibiting the active participation by females which, as a result, negatively impacts their educational outcomes (Heller, et al. 1985).

Teaching practices and learning styles have been found to affect females more than males in computer-related subjects. Studies have shown that even females with high computer self-efficacy prefer a co-operative learning style (Salminen-Karlsson, 2009). However, such learning styles are not popular with computing teachers in schools (Barker, et al. 2002) and research has shown that STEM subjects tend to be taught in a more strict, lecture- orientated style than other disciplines (Packard, et al. 2011). One result of this poor pedagogy is that female students’ negative experiences in computing at lower levels (say, Key Stage 3) often have a detrimental impact on whether they decide to continue to study computing later at, say, GCSE or A Level (see Zarrett, et al. 2006; Cohoon & Cohoon, 2006). As Cohoon and colleagues suggest, a good first experience in computing courses is vital for successful recruitment to the subject at later stages (Cohoon, et al. 2013).

Turning now to the gendered nature of social interactions in the classroom, and research has shown that when female students have a female computing teacher in post-primary they are more likely to take computer-related courses at university (Beyer & Haller, 2006). The suggested reason for this is that exposure to female role models changes female students’ internal self-beliefs (e.g. builds their self-efficacy) and enables them to envision themselves in those roles (Asgari, et al. 2012). Lin calls this effect ‘social persuasion’ – where positive role models convince individuals that they have the ability to successfully complete a specific task, [meaning] they tend to make a greater effort than would otherwise be the case’ (Lin, 2016). This is particularly important as (male) computing teachers have often been described as less supportive than teachers in other subjects (Barker, et al. 2002). Similar effects have been observed at Universities, where female students studying STEM under female lecturers are more likely to consider a role in a STEM-orientated career (Amelink & Creamer, 2010). In sum, the gender of the teacher matters and, for females in computing, greater numbers of female teaching staff could have a positive influence on females’ decisions to not only study computing but to persist with studying it.

As for gendered interactions between students themselves, peer encouragement has been found to predict intention to study computing-related subjects (Denner et al. 2014). This means peer-to-peer respect between students, both male and female, is paramount if a positive teaching environment is to be fostered, and sense of belonging cultivated, within the computing classroom (Barker, et al. 2009). However, stereotyping persists within the classroom and, as research has consistently shown, females and males generally believe males to be better at computing than females. Moreover, males are more likely to hold stronger stereotypes in this regard than females (Durndell, et al. 1995). Obviously, this problematic attitude does pose a serious challenge to the maintenance of mutual respect and positive peer encouragement in the classroom – and has even led some scholars to assess the relative performance of female computing students in mixed gender classes against single gender classes. The results of these studies were contentious but, interestingly, two themes did emerge: (i) females in single gender classes had a higher baseline computer self-efficacy (Galpin, et al. 2003), and (ii) males were much more likely to collaborate in mixed gender classes (Underwood & Jindal, 1994).

Finally, the structuring of computing curriculums. In this regard, the existing research is limited and non-confirmatory. However, criticism of the standard computer curriculum does include its exclusive focus on programming (Schofield, 1995), its emphasis on mechanical skills as opposed to problem-solving (Goode, et al. 2005), and that more complex and stimulating projects are frequently earmarked for advanced courses that arrive too late for most female students (Linn, 2005). As with much gender- orientated criticism of educational programmes, though, much of the research into the computing curriculum is underlain by the awkward presumption of female homogeneity (e.g. that all females learn the same way and want to learn the same things). This is manifestly not the case, with suggestions that females do not enjoy programming as much as males, for example, is plainly too general and thus inaccurate. This is not say, however, that all aspects of the computing curriculum are gender-neutral or necessarily inclusive. Rather, as suggested in the section below, new and novel forms of computer study are emerging constantly – many of which are aimed specifically at encouraging gender-neutral computing (e.g. Inclusive ICTs) and enjoyment for both genders equally.

(b) At Home

While concerns about the experiences of female students in computing classrooms are significant, researchers have also observed the experiences of females using computers at home as contributing to low self-efficacy. In decades past, these concerns have been framed strictly in terms of access to a home computer. However, now that around 88% of UK households contain a computer and most schools have sufficient hardware, this complaint has retreated. Instead, concerns have broadened to include the competition from males faced by female young people at home for time on the computer (Gunn, 2003) – particularly significant because students can often get as much access to a computer in one weekend at home as in an entire year at school (Linn, 2005). When trying to address the issues of computer anxiety and confidence, the relative lack of time spent on a computer at home by females has detrimental implications.

Beyond this, concerns about access have also substantively re-focused on the socio-economic status of the families involved. Children living in more economically deprived areas have been shown to have more limited access to computer resources at school, compounding the fact they are less likely to have computers at home. Access to a computer at home is a particular issue for children, both male and female, coming from households of lower socio-economic status. However, with digital technology becoming more ubiquitous, socio-economic concerns are now 'overshadowed [by] the stronger influence of parental attitudes' (Shashaani, 1994; See also Downes & Looker, 2011; Álvarez, et al. 2013; Symons, et al. 2017).

Parents' attitudes towards their children's use of computers and digital technology have a significant impact on the children's experience of it. Studies highlight three aspects of this concern as critical: (i) the presence of a domestic role model for children, particularly females; (ii) the degree of computer access afforded to children by parents; and (iii) parental influence on females' career choices, usually stemming from existing cultural stereotypes.

Regarding the need for a domestic role model, studies have shown that a home environment without any 'female-user role model… may [negatively] influence females 'self-confidence. [This may result in them feeling] that learning and working with computers are difficult tasks and that computers are in the masculine domain' (Shashaani, 1994). This reflects the contention outlined above concerning the need for positive female role models in the computing classroom. At home, females need to feel encouraged to engage with the computer in a range of different ways, to go beyond their own perceived limitations and thereby grow their sense of belonging within the computing environment. This would be aided with progress on the second issue, the level of computer access afforded to and taken up by female children. As studies consistently evidence, males experience computing at a younger age and are, on average, given more free-time exploratory use of the computer throughout their childhoods (Snyder, et al. 2004). As liberal feminist Ann Oakley (1982) found, parents 'channel' their children towards toys appropriate for that child's gender, so the stereotypical perception of computers as a masculine interest is of importance (also Halpern & Perry-Jenkins, 2016). Research findings underscore the observation that intensity of interest in computer use is intrinsically linked to computer literacy, and thus self-perceptions of competence and confidence (Varma, 2011). Given males tend to dominate in intensity, therefore, this could be considered a primary reason for males' higher levels of computing confidence (Tella & Mutula, 2008) and reported openness to new digital technologies (Okebukola & Woda, 1993).

The third aspect of parental influence that impacts females' participation in computing at school is parental pressure on females to adopt 'female' career paths (Sáinz, et al. 2011). As research released to mark the seventh International Girls in ICT Day to 2017 found, UK parents 'picked traditional jobs such as doctor (24 percent), teacher (20 percent) and lawyer (17 percent) as the top preferred careers for females'. By way of comparison, 'engineer (21 percent), tech entrepreneur and game developer (both 13 percent) all featured in the top five preferred careers for [males]' (Pudwell, 2017). This confirms what previous studies have argued (Fulcher, 2010; Halpern & Perry-Jenkins, 2016), therefore - that a considerable gender bias still exists for parents when encouraging their children into particular careers, and that this gendering of particular jobs dictates parental concerns over what their child's skills and knowledge should be (i.e. a lack of concern about a female having a low knowledge of coding because coding is a boy's activity).

(c) Within Popular Culture

Aside from females' experiences of computing in the classroom and at home, there remains the significant influence of broader popular culture on females' attitudes towards computer and digital technology. There is, of course, the crucial interplay of stereotyping and real-world practice within popular culture, and this has led scholars to ask difficult questions about the resources for computing available to younger females, particularly. As some have pointed out, the principle way in which children interact with computers, particularly in their leisure time, is through using various pieces of software, mostly games and applications. However, software is itself gendered, with the very existence of software designed ‘for females’ testament to this. Historically, software was designed by males for males (Kiesler, et al. 1983) and its development since has continued along gendered lines. Games and applications produced for females are often conceived, in subject or task, based on gendered stereotype: “shopping, makeup, fashion, dating” (Rubin, et al. 1997). This is then reflected in the gendered nature of the characters, content, and structure of the games or applications (Bhargava, et al. 2002). As Linn detects, software titles for females ‘perpetuate sexism and serve only to enrich the companies that produce them’ (Linn, 1999: 16).

Interestingly, the gendering of software even penetrates education software. In their study, Huff and Cooper (1987) asked teachers at all levels of schooling to design educational software for their students. The teachers followed gendered stereotypes, and designed tool software for the females and software involving competitive violence for the males. When Huff repeated the experiment 15 years later, he found the same result. Huff concluded: ‘it is not the computer, or even the software, that is at the root of the sex bias in software, but the expectations and stereotypes of the designers of the software.’ (Huff, 2002: 519). In other words, such is the influence of cultural stereotypes that even teachers can fall foul of them – implying a need to be highly sensitive to the design of educational software in the future to ensure inclusivity and gender-neutrality.

Beyond the gendered nature of software, there is also the pressing issue of sexist discrimination within the computing sector generally. Social media and the internet have unleashed new ways for gender-based stereotyping to be enforced and acted upon, sometimes violently. Perhaps the most relevant example of this is the ‘#GamerGate’ controversy in which several females in the video game industry were harassed online by large numbers of predominantly male internet users (Dewey, 2014; Wofford, 2014). Websites like Reddit and Twitter enabled the harassment to become very large-scale, becoming viral in a short amount of time. As a cultural spectacle, #GamerGate was a devastating indictment of an internet culture imbued with extreme sexism and trolling. (Other studies have found online gaming and streaming on websites like YouTube and Twitch to be deeply permeated with sexism, with those males involved finding gender discrimination in the real-world more acceptable as a result – for a review, see Paaßen, et al. 2017). For females in the computer industry #GamerGate was a frightening experience, and it will have done much to further females’ existing feelings regarding a lack of belonging in the computing environment (see Massanari, 2017).

(d) As a Career Prospect

The final way in which females may experience computing is through contemplation of the field as a potential career path. As the literature indicates, there is a wealth of conflicting research into what either attracts or dissuades females from careers in computing. Some theorise that encouragement from appropriate mentors is the most influential factor, while others view a combination of the future job market, existing interest and suitable personality type as utmost relevant. Where there is relative consensus, however, is in the notion that the decision-making process of females (and males) when it comes to careers in computing is imbued with a range of popular misconceptions. This is not the fault of the individuals involved, of course, but rather the outcome of gendered stereotyping and, to some degree, misunderstandings of what 'computing' actually involves.

One of the most prevalent misconceptions, for instance, is that computing (and specifically, programming) is a solo activity and therefore not suited to females who prefer team-based jobs involving greater social interaction (Margolis & Fisher, 2002; Zimmerman & Sprung, 2008). As Carter (2006) found, this is a popular reason females give for not participating in computing or pursuing careers within the field. Yet, as Doolan (2014) argues, in the present market place computing jobs involve highly varied roles where employees are expected to do anything from travelling across the world to meet clients and designing applications, to presenting ideas to senior management. Thus, social skills like good communication, alongside technical skills, are essential to a career in computing. Moreover, research has shown that if these skills are demonstrated or highlighted to females before they choose their educational courses, it has the potential to significantly increase the rate of application for computing-related subjects (Graham & Latulipe, 2003). In other words, early intervention is crucial – by stressing to females early in their school careers that roles within the computing and digital technology sector are malleable both in type and skill-requirement, female participation in computing subjects can be increased at later stages.

A further misconception relates the popular claim that computing jobs are 'boring' and do not offer the same variety or excitement that other roles might (Grant, et al. 2007; Papastergiou, 2008). This perception, it is claimed, is more damaging to females than males because it is amplified by the already existent stereotypes and images of computing as a masculine domain perpetuated through popular culture (Fisher & Margolis, 2003). There are many ways of disproving this misconception including, but not limited to, drawing attention to the testimonies of females already working in high tech industries. Third sector organisations like 'Women in Tech' (https://www.womenintech.co.uk/) in the UK and 'Women in Technology' (https://www.womenintechnology.org/) in the US are already committed to disseminating such testimony at schools and Universities. With the objective of de-mystifying the computing sector for females of all ages, these organisations work to disassemble the structural barriers faced by females when considering a career in the tech industry.

The popularity of these misconceptions is a major hurdle in the encouragement of females into computing careers and, by implication, computing at school. Even though they can be easily disproven, the ideas resonate widely – often taking the place of more factual concerns. For instance, the computing sector may offer wide-ranging job opportunities for females, but the industry's most common role – that of computer programmer – also has one of the biggest pay gaps (22%) between males and females in the UK (Tobin, 2016). This, coupled with continuing scandals for tech giants involving alleged sexist recruitment practices (Hicks, 2018), make for a much bleaker outlook for females considering computing careers.

Overall, therefore, the combined experiences for females in computing - in the classroom, at home, in popular culture and as a career prospect – do present problems for female participation in computing at school and university. Feeding computer anxiety and further alienating females from a sense of belonging within the computer environment, these experiences contribute to the production of barriers that discourage females from studying computing-related subjects. Thus, we must find ways of promoting positive computing experiences for females within these realms of their lives, thereby helping to cultivate a mature sense of belonging that will encourage greater female participation in computing at school.

4

Strategies for Increasing Female Participation in Computing

4 Strategies for Increasing Female Participation in Computing

The reasons underlying the low participation of females within computing stem from cultural stereotyping and the resultant lack of a sense of belonging within the computing environment felt by female students. Leading to an increase in computing anxiety and low self-efficacy, stereotyping creates complex barriers to female participation that are acutely difficult to overcome. By virtue of their emergence through the cultural paradigm, these obstacles cannot be tasked by actions of educators alone – instead, a broader cultural shift towards greater gender diversity. Inclusivity and recognition is needed. That said, this does not preclude educators from contributing to the required cultural shift – in many ways, they are in a prime position to lead it. However, this does require the acknowledgment that past interventions by educators to increase female participation in computing have had mixed results, with signs of success only occurring in the long-term. Thus, it is with this caution in mind that this section outlines a number of potential strategies for fostering greater levels of female participation in computing-related subjects at school. Ranging from the anecdotal to the evidentiary, the literature is awash with potential strategies, making reaching a satisfying synthesis difficult - but some suggestions can be listed. Overarching, the strategies discussed here involve lessening the barriers to female participation brought about by stereotyping by seeking to cultivate a sense of belonging for females within the computing environment in schools within NI. These strategies include: the need for further research at a regional level that builds on existing research by both the Royal Society (2017) and the University of Roehampton (Kemp & Berry, 2019); the alteration of teaching environments towards greater inclusivity; the diversification of teaching methods; and the incorporation of teaching programmes centred on the use of Inclusive ICTs, such as the international project 'No One Left Behind' (NOLB) funded by the EU's Horizon 2020 Framework for Research and Innovation.

Further Research in Northern Ireland

A first major step in improving female students' participation in computing subjects (GCSE and A Level) in NI would be the production and commencement of a comprehensive research agenda. While data exists in a multitude of studies on female attitudes to computing and participation at schools and Universities internationally, no such research focuses on NI specifically. This gap in the research implies that it is currently impossible to state which of the barriers identified within this paper are most prevalent or influential in the NI context. This is evidenced by studies like that conducted in Sweden by Eriksson & Lindholm (2007) where they found stereotype threat among female students was, against expectation, very weak in that national context. Thus, without such in-depth research, potential remedies for low female participation within computing subjects in NI can only be spoken about tentatively. Ideally, and by taking inspiration from existing studies, this NI focused research would concentrate on three areas:

- The perspectives and opinions of NI female students with respect to computing at school and as a career, focusing specially on what kinds of barriers to participation are perceived (e.g. sense of belonging, computer anxiety, stereotyping, etc.);

- Pupil and teacher views on the current computing curriculum, with explicit attention paid to any gendered aspects of its content or delivery; and,
- The potentially gendered nature of the computing classroom, particularly the gender of teaching staff, teaching methods, teaching environment, and expected learning styles.

A comprehensive research project that investigated these three areas of critical interest in the NI context would be a significant step forward in terms of strategising against the low rates of female participation in computing at school.

It can be further suggested that this potential research project should incorporate a mix of both quantitative and qualitative methodologies. As previous studies in other national contexts have shown, female students' views on computing are complex and far from homogeneous. By first using a quantitative strategy (i.e. online survey) to establish the overarching trends (e.g. barriers to participation), follow-up investigations deploying qualitative means (i.e. focus groups, pupil parliaments) can further investigate popular themes of inquiry and, importantly, potential solutions. Engaging researchers with students in this way should allow for constructive conservations to develop within the investigation and, most significantly, for the voices of female students to be heard. Indeed, it could be argued that the very action of listening to the concerns of female students about computing education is a necessary and purposive step in itself; allowing females to feel that their anxieties are being recognised, that they are being encouraged to feel a sense of belonging, and that those involved with teaching computing care enough to listen.

It is worth noting that if a research agenda concerning females in computing were to be designed and implemented for NI, both the Royal Society's 2017 report 'After the Reboot: Computing Education in UK Schools' and the 'Roehampton Annual Computing Education Report' for 2018 (Kemp & Berry, 2019) would be useful starting points for engagement. A wide-ranging quantitative study, the Royal Society report confirmed for the whole of the UK that computing-related subjects were male-dominated in terms of participatory numbers. The authors claim that widening access to females, the economically disadvantaged, and pupils with special educational needs and disabilities (SEND) should be a priority for UK governments going forward. Although this report was strictly policy advice (and not policy itself), its call for increased funding for courses and programmes dedicated to growing the participation of minorities within computing (such as 'the Network of Excellence') was clear. Thus, should a research agenda for NI be forwarded, engaging with the Royal Society on this basis may be a fruitful and productive initial step – perhaps allowing NI to make clear its case for incorporation in any newly emergent or successfully recognised educational inclusion strategies in both the near- and long-term. The annual Roehampton report for 2018 backed up the findings of the Royal Society by pointing to a fall in the number of pupils overall gaining a GCSE in ICT or computer science in England (140000 in 2017 to 130000 in 2018). The report attributed this fall in part to the phasing out of the ICT GCSE in England and, moreover, to a significant drop in the amount of time (per week) spent teaching computing in the average KS3 or KS4 classroom. These are the types of meaningful research findings, then, that have real-world implications for female (and male) participation in computing at school. As such, further research at a regional level should aim to build upon these findings, identifying the similarities or differences in the present trends in computing at school within NI.

Tackling the Cultural Stereotype: Integrating Role Models

Withstanding the lack of current NI specific research, a popular remedy for increasing female student participation in computing is tackling stereotype threat through the promotion of visible role models. This, it is claimed, allows for a sense of belonging to be cultivated among females through social persuasion – in other words, encouragement and active inclusion (Linn, 2016). As studies have found, addressing gender stereotypes about intellectual ability from an early age has a beneficial impact on lessening anxieties around learning later in a student's life (Bian et al. 2017). This has a particularly significant influence when it comes to computing, where challenging previously fixed mind-sets around the participation of females in computing roles has been shown to have a positive effect on learning outcomes at schools (Cutts et al. 2010). It is for this reason that many government and third sector institutions have taken up the mantel of promoting female role models within the fields of computing and digital technology. As previously mentioned, 'Women in Technology' is forbearer of this practice in the UK – enabling a broad range of women, including those from a variety of racial and ethnic minorities, already working in tech-based roles to share their stories with others. 'Women in Technology' have then compiled these testimonies into a selection of guides and literature, all aimed at promoting advice and opportunities for females entering (or thinking about entering) the field at all ages. Thus, working with organisations such as 'Women in Technology' to promote positive female role models in tech within school settings could be an advantageous step towards de-mystifying computing as a male-domain, thereby helping to stimulate a sense of belonging for female students.

It is worth noting, however, that the promotion of role models does carry some risks. For instance, promoting overly successful role models, or role models with un-relatable stories (e.g. those that started with extensive levels of privilege or un-relatable levels of ability) can reinforce gender stereotypes by further exceptionalising the individuals involved. For this reason, the role models presented to students have to be relatable, realistic representations of what is achievable by students overall – especially significant given females have existing issues with low computing self-efficacy. Otherwise, as research has shown, the promotion of role models can undermine the project of stereotype contestation, further stigmatising study and careers in computing for females (Cheryan, et al. 2011).

Another way of promoting positive role models within school settings is to work directly with the local tech industry through the organisation of dedicated events or open-days. Such events, that bring students and workers together, can have a motivating effect on young people, giving them the opportunity to hear from those already in the workplace. Open-days are also often an opportunity for students to get hands-on experience with the kinds of tasks expected in particular computer-based roles. The companies involved can demonstrate to the students not only their products, but the processes that went into their design and manufacture. As noted in section 2, a common complaint among some female students is that computing can be a boring, isolating experience. Giving students the chance to see all of the different aspects of design and production, alongside the very contemporary work environments that many tech firms have, should go some distance in contesting this. In this respect, the NI context is fortunate. With considerable growth in the computing and tech sector locally in recent years, and the emergence of various notable start-ups, there are a wealth of industry resources to be called upon and integrated. Some local companies - like Kainos, Liberty, Intel and BT - already have out-reach programmes that include work placements for students at schools and Universities. Working with these firms to integrate and prioritise female participation would be another way in which female students might be encouraged to study the subject further, with the objective of entering the sector.

Changing the Teaching Environment: Inclusive ICTs

Alongside challenging cultural stereotypes through the promotion of positive role models, research suggests that alterations to the computing learning environment are needed if more female students are to cultivate a sense of belonging and choose to participate in the subject. This places a focus on the role of educators themselves, and the interventions they can make – in the classroom, to their teaching methods, and to the computing curriculum – to ensure equality and inclusivity are brought to the fore. A wide range of possible interventions are suggested within the literature, and the results are consistently mixed. However, a number of interventions, dating back to the nineties, can be highlighted as being most commonly considered effective:

- Educators can teach students about stereotype threat and the illegitimacy of stereotypes alleging minorities' and female's inferior intellectual and computing ability (Johns et al. 2005).
- They can encourage students to see intelligence as malleable rather than fixed, with tasks often requiring sets of different, non-aligned skills (Aronson et al. 2002).
- Teachers should use diverse examples in class discussions, thereby providing all students with an inclusive range of role models (McIntyre et al. 2005).
- They can communicate to their students that they are welcomed, supported, and valued, whatever their background or self-perceived level of ability (Davies et al. 2005).
- When providing critical feedback to minority students, they can emphasise their high standards and assure students that they can meet these high standards (Cohen et al. 1999).

Thus, when approaching their personal teaching practice and planning, educators can take steps to ensure equality and diversity are achieved. The impact of these changes can be expected to be gradual and long-term but, by doing so, they can contribute to a cultural shift within education systems and schools. When trying to increase the participation of females in computing, however, it is this cultural shift that is key – altering established stereotyped mind-sets through small changes to individuals' teaching practice.

Beyond this culture shift within educational institutions themselves, two more precise themes emerge from the literature concerning increasing female participation and their sense of belonging through changes to the standard computing curriculum. First, it is frequently argued that there is a need to make the computing curriculum more relevant to real-world concerns - partly by making it cross-disciplinary. This stems from the idea that, as it is, computing is generally a male- orientated and abstract curriculum, devoid of much social relevance (Margolis & Fisher, 2002). As Margolis and Fisher (2002) recall, this is a problem because research shows that female students find social and ethical questions more interesting than plainly abstract ones. For this reason, they call for a new curriculum centred on 'computing with a purpose', one that places the functionality of computers 'within human and social contexts' (Margolis & Fisher, 2002; also McCormick 1992). One way of doing this is to ensure technology is infused across a flexible curriculum, allowing computing skills to be utilized in relevant ways in different educational and social contexts – something that should appeal to female students as it moves the computer out of the lab and into more diverse, less stereotyped domains.

Second, there are calls within the literature for schools and teachers to employ different curricular approaches and teaching methods to appeal to a range of diverse learning styles. For the computing curriculum, this implies movement away from isolating coding activities towards practice centred on social interaction and communal learning. As one study in the UK demonstrated, useful in this respect can be programmes such as 'taster' courses which can be created with female students in mind (Dain, 1991). Taster courses offer female students a glimpse of computing without the need to commit, while also promoting the difference ways in which computing can be learned and taught. This is a further way in which the computing curriculum can be tailored to improve female participation – but, as with most of the existing research, the results of these interventions are contested, with improvement likely to come only in the long-term through a broader cultural shift inside and outside of the classroom.

One of the main reasons the results of studies into curriculum changes based on commonly accepted gender differences are contested is that, from a critical perspective, it is easy to perpetuate existing stereotypes by presuming homogeneity in females' learning styles and desired outcomes (Blum & Frieze, 2005). Due to this risk, the trend in contemporary research is to search for gender-neutral ways of engaging both males and females equally in computing and digital technology – known commonly as 'Inclusive ICTs'. A prime example of this is the BBC's 'micro:bit' (https://microbit.org/) - a handheld, programmable computer that is distributed to 10 and 11 year olds across schools the UK. Aimed at increasing pupil engagement with basic coding, the micro:bit has had considerable success encouraging female students to pursue computing, with BBC statistics suggesting an increase from 23% to 39% in females indicating favourability towards a career in the field after using the device (BBC, 2017). Others Inclusive ICTs include those supported and disseminated through Nominet Trust, including 'Apps for Good', which assists students in the creation of technology-based solutions to problems that concern them; 'Code Club', a nationwide network of after-school coding clubs; and the 'BAFTA Young Game Designers Competition'. Initiatives like these can help demystify computing for young people of both genders and, as a consequence, contribute to the breaking down existing stereotypes and cultivation of a sense of belonging for female students in the computing classroom and wider environment.

'No One Left Behind'

Outside of UK-based projects, of the initiatives centred on Inclusivity ICTs globally, a promising project has emerged from the Graz University of Technology (TU-Graz) in Austria. Backed by European funding, the 'No One Left Behind' (NOLB) project (http://no1leftbehind.eu/) is focused on integrating a game-making teaching framework into the educational app 'Pocket Code' (Spieler, et al. 2017; 2018). Pocket Code is an Android-based mobile application that allows users to create their own games, animations, interactive videos, and other types of apps directly on their mobile phone or tablet device; something that contributes to inclusivity on socio-economic grounds insomuch as students without a computer at home tend still to have access to a mobile phone or tablet. Pocket Code uses a visual 'Lego'-style programming language called 'Catrobat', which is very similar to the coding language Scratch. This is considered a principle advantage to the programme given that many schools and teachers already use Scratch within coding lessons. Research and piloting of the NOLB project started in January 2015 and ended in June 2017, and involved schools in Austria, Spain and the UK.

According to the lead project researchers Spieler and colleagues, the designated purpose of NOLB is to create highly flexible, pupil-led learning programme that supports teachers in the integration of coding into their classes across the curriculum. As they state, NOLB aims to '[help] students to take control of their own education, becoming more engaged, interested, and empowered as a result' (Spieler, et al. 2017). Crucial to this were two steps: first, the creation of Pocket Code as a sufficiently flexible and innovative tool that would allow for multiple types of apps to be designed and used; and, second, the training of teachers from different technical and non-technical backgrounds in the integration and implementation of Pocket Code within the diversity of their teaching plans and lessons. Importantly, within the pilots, students were encouraged to create games that referred to different subject areas and their own interests, making Pocket Code a truly cross-curricular tool. The challenge then was to provide teachers with sufficient guidance to make Pocket Code an effective and accessible teaching tool.

Two principle research studies have been published concerning the piloting and testing of the NOLB programme, in 2017 and 2018. The first study (Spieler, et al. 2017) focused on a small-scale pilot in an Austrian school. Children were asked to use Pocket Code to design an app applicable to a subject of their choice – these ranged from music to history to computer science. Research was then conducted through qualitative feedback from the teachers and students involved. On this occasion, the feedback from both was mixed. On the one hand, children were found to enjoy the playful aspect of Pocket Code, but also felt overwhelmed by the amount of coding knowledge they were expected to know or find out for themselves via the internet. Teachers, on the other hand, reported seeing great potential in the varied functionality of the app, but also worried about their own lack of skill (particularly if from a non-technical background) and the poor learning outputs from some students. Both groups also reported being slightly disappointed with the presentation and sophistication of the app; a complaint the researchers put down to the participants existent experiences with other modern, more polished software. These findings then led to the second substantive study (Spieler, et al. 2018), the purpose of which was to refine the guidance given to teachers in the use of Pocket Code as a teaching tool, alongside the introduction of coding templates to ease concerns over the level of pre-existent knowledge required by students. The results of this pilot were more positive than previous, with the availability of templates receiving particular praise as they freed up students' time to pursue their learning outcome rather than worrying about functionality.

Considering the overall progress made on Pocket Code as an educational tool there is clearly promise in its application within the classroom. Both its flexibility and its cross-curricular focus are significant attributes in enabling the teaching of computer and coding skills outside of the computing lab. In this way, it promotes access to coding to female students, as well as male students, throughout the school and across curricular subjects, with its play-based design helping demystify the often narrow, boring image of coding as a male-orientated activity by opening computing activities to females, letting them cultivate a sense of belonging.

Government and Third Sector Initiatives – Raising Awareness

Undoubtedly the incorporation of Inclusive ICTs will be crucial, in changing the approaches to teaching computing within schools and to cultivating a sense of belonging for females within the subject area. However, with such programmes mostly in their foundation stages, the outcomes for female participation levels in computing (particularly in terms of career choice) will not become obvious for some years. In the intermediate time, one further remedy can be discussed: increasing female students' general awareness of the possibility of careers in computing. As research from industry body CompTIA identifies, a key cause of females not entering tech careers is females of school-age lacking awareness about their career opportunities: 'Of girls [or females] who have not considered an IT career, 69% attribute this to not knowing what opportunities are available to them' (CompTIA, 2016). This is a stark claim to be made in 2016, especially when one considers the efforts being made by companies and governments alike to promote the tech sector as a career possibility for females. Indeed, there is an extensive range of campaigns by governmental bodies, third sector organisations, and private companies alike, advocating for female participation in the fields of computing and digital technology:

- International Girls in ICT Day, supported by large tech corporations like Cisco, is celebrated every year on the fourth Thursday of April and was last observed on 25 April 2019.
- The 'WISE Campaign's People Like Me initiative', backed by UK government and UK Space Agency
- Starter programmes and employment workshops by, for example, 'Girls in Tech' (https://girlsintech.org/), and 'The CIO Development Women Leaders in Technology' (https://www.ciodevelopment.com/girlsinit/). The latter ran a campaign in 2015 to promote IT for girls aged 11 to 14 that promoted 1000 female role models in 4000 UK schools.
- Female-orientated apprenticeship schemes operated by many tech firms, including ITEC (https://www.iteclt.co.uk/apprenticeships/it-girls).
- Computer clubs for girls and females, including the 'Code First: Girls 2020 campaign' (https://www.codefirstgirls.org.uk/) and 'Girls in Tech London' (https://london.girlsintech.org/). The latter operates an online global classroom for females and holds periodic special events, such as hackathons.

From an advocacy standpoint, then, there is clearly not a lack of resources being devoted to the question of tackling low female participation in computing. Rather, the problem is found in effectively disseminating those resources and in raising general awareness among particularly younger females.

As with all careers awareness, there are inherent difficulties in making younger people consider their future careers and the skills they will need to pursue them. However, greater integration into schools of resources that do inform students, particularly females, about careers in computing would evidently be useful. This need is amplified by the fact that the computing sector is always changing, with traditional roles falling away and new skills constantly in demand. As Cassel point out, computing is becoming more interdisciplinary all the time as companies expand through innovation, and computing skills are becoming relevant in fields far beyond traditional computing work (Cassel, 2011). Thus, computing skills are valuable in virtually all workplaces and sectors – from marketing to retail, from sports science to education. The need to make female students aware that computing is more than simply coding is paramount if the skill gaps of the future economy are to be filled.

Beyond this, and as an addendum, it is also vital that female students are made aware that, as consumers of digital technology, it is important that their interests are reflected in their manufacture. There are many examples of how technology companies have overlooked females and their needs when developing new products, from voice recognition software that does not accurately hear females' voices (Margolis & Fisher, 2002) to personal assistant apps (e.g. Apple's Siri) that fail to respond to crises that disproportionately affect females, such as sexual assault or domestic abuse[1] (Miner et al. 2016). When more females are a part of developing new technology, they can help design products that better serve the needs of males and females. Making female students aware of these implications when they are faced with their career choices should provide extra motivation, if it is needed, for them to pursue computing at school and university.

[1] Research showed Smartphone- based conversational agents failed to recognise statements relating to sexual assault and domestic violence but could recognise health concerns.

5

Conclusions

5 Conclusion

This paper has sought to establish why the participation of females in computing-related subjects in NI is low compared to males, and the types of interventions that might remedy the gendered disparity. It has been the contention of this paper that the total entry numbers of females into computing-related subjects in NI schools at GCSE and A Level is much lower than that of males and that the primary causes of this differential stems from cultural stereotyping. Specifically, it is the stereotyping of computer users as male, socially awkward and intense that dissuades females from feeling a sense of belonging in the computing environment. This lack of a sense of belonging may cause females to experience increased computer anxiety and lower self-efficacy, further undermining their confidence in the use and study of computers. When combined, these factors establish significant barriers to female participation in computing at school, reflected by the low level of female entry across GCSE and A Level in NI.

Crucially, many of these conclusions researched through the synthesis of literature undertaken by this paper are reflected by the findings of the 2017 Royal Society Report:

> *'The researchers found that school culture played a key role in influencing how pupils view and choose certain subjects. The researchers also found that providing pupils with careers guidance at an early age, and promoting a gender champion from the senior leadership team, could have a positive impact on gender biases. The work undertaken by the Institute of Physics is very promising and the Government should consider funding further research to explore whether the model has potential for computing and other gender-skewed subjects.'*
>
> (Royal Society, 2017: 44)

Thus, the findings of this paper do reflect broader concerns across the UK about female participation in computing – implying that any future developments across UK schooling should be monitored by those in NI, with successful initiatives either adopted or investigated as potential remedies.

On that note, the remedies outlined in this paper were considered in line with the need to cultivate a sense of belonging for females within the computing environment; a sense of belonging that would help overcome the barriers put in place by the existent cultural stereotyping against females in computing. These methods of cultivation included:

Further research into the NI educational context. This was suggested, firstly, because no such research currently exists for NI, only the UK overall and, secondly, to help more accurately establish which barriers females felt more compelling in their choice not to pursue Computing at GCSE and A Level.

Integration of Role Models into schooling programmes. The reason underlying this is the belief, supported by some in the literature, that the integration of positive female role models from the local tech industry can aid in dissembling the existing stereotypes associated with computing, thereby lowering the anxieties felt by female student brought about by stereotype threat. There was some concern, however, that these role models had to be realistic representations of aspiration as un-relatable role models can undermine the confidence of those they are trying to inspire.

Changing the teaching environment. The most significant impact educators can make in cultivating a sense of belonging for female students within computing is to address the gendered aspects of their teaching practice – specifically, concerns with the gender of teacher, their teaching methods, and the computing curriculum. It was suggested that female students have been shown to persist with computing for longer if they have a positive female role model in the classroom, if the teaching methods used in class involve greater social interaction, and if the computing curriculum is more diverse – incorporating more real-world problems and societal contexts.

Inclusive ICTs. An important element in the changing the teaching environment is the inclusion and application of Inclusive ICTs - computer programmes and applications that are designed with gender-neutrality in mind. A purposive example was investigated: the No One Left Behind project. This project, which integrated a mobile application called Pocket Code into a variety of teaching plans, allowing students to create their own educational programmes through game-based interactions, had seen considerable success in uptake with females. It was suggested that initiatives such as this are a prime way of allowing females to familiarise themselves with complex computing functions (e.g. coding) outside of the computer lab, thereby allowing their sense of belonging in the computing environment more generally to grow.

Promoting computing as a career choice for females. Research has shown that females at post-primary have low levels of awareness when it comes to computing careers. Integrating industry and third sector groups through open-days and school events is a straightforward way of attempting to resolve this, therefore, with an emphasis placed on the diversity and malleability of computing careers.

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6

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