Woman's under-representation in STEM: The part role-models have played in the past and do we still need them today?

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Abstract

In 2005, Blickenstaff wrote that woman were under-represented in science, technology, engineering and mathematics (STEM) in both education and careers in most industrialised countries around the world. This under-representation is not something new, it was identified as problematic as early as the 1980s (Kelly et al.,1981; Smail et al., 1982). While encouraging girls to study and pursue careers in the technology sector continues to be problematic even today (Bauer, 2017).

After introducing the topic, the paper begins with a brief discussion of some of the factors that researchers have believed influenced this under-representation. Several ways forward to improve the state of affairs from the literature are then discussed, before turning to concentrate specifically on role-models and the part that they can play in changing the situation.

The next section focuses on the author's personal experiences of being a role-model in a male-dominated workplace in the mid-1960s when she started her career as the first qualified female woodwork teacher in the UK having trained as a product designer and maker of furniture.

This is followed by a discussion of various research projects concerned with the positive effects of role model exposure in terms of: motivating individuals through acting as behavioral models, representing the possible, being inspirational; improving a sense of belonging; impacting on academic self-efficacy; and negating stereotypes.

The final section looks at very recent research and comes to some conclusions about the question posed in the paper's title: Do we still need role-models today?

Key Words: Key word 1 Role-models, Key word 2: under-representation, Key word 3. STEM

1. INTRODUCTION

The aim of this paper is first to analyse and discuss factors from relevant literature that have influenced woman's continued under-representation in science, technology, engineering and mathematics (STEM) education and subsequent careers. This is followed by an analysis and discussion of role model literature concerning the positive and negative effects that exposure to role models has had, and the forms that such role models have taken in order to improve women's representation in STEM. The author's personal experiences of role models and being a role-model herself have been woven into the discussion. The final section sums up the findings and provides some conclusions concerning whether or not role models are still required today.

2. WOMEN'S UNDER-REPRESENTATION

In 2005, Blickenstaff wrote that women were under-represented in STEM, in education and careers in most industrialised countries around the world. This concern had been highlighted in 2002 by Baroness Greenfield (2009) in her *Report on Women in Science, Engineering, and Technology*.

> The under-representation of women in science, engineering and technology threatens, above all, our global competitiveness. It is an issue for society, for organisations, for employers and for the individual. (Greenfield, 2002, p.9.)

This state of affairs has been debated by many others (e.g. Darmody & Smyth, 2005; Shin, Levy & London, 2016; Smith, 2011; van Aalderen-Smeets & Walma van der Molen, 2018) and remains an area of political priority and concern (Smith, 2011) in terms of education and the current and future job market (Noonan, & Laffarge, 2017) even today. This is a complex issue (van Aalderen-Smeets & Walma van der Molen, 2018). It is not something new (Atkinson, 1997). It was identified as problematic as early as the 1980s (Kelly Smail, & Whyte, 1981; Smail, Whyte, & Kelly, 1982), with unequal participation in STEM subjects remaining virtually unchanged for the past 35 years (Smith, 2011; Ceci, Williams & Barnett, 2009; Noonan & Laffarge, 2017). This has been despite initiatives such as the introduction of comprehensive education, equal opportunity legislation and many interventions specifically targeted at encouraging female participation in various aspects of STEM. For example: TVEI – Technical and Vocational Education Initiative in 1982; WISE - Woman into Science and Engineering in 1984; GIST – Girls into Science and Technology in 1985 and jumping to more recent times, Girls in Tech in 2007, Technovation in 2010 and Little Miss Geek in 2012. Added to these has been the compulsory participation of all pupils in STEM subjects in primary and lower secondary level since the introduction of the National Curriculum (Atkinson, 1997) and a willingness by many STEM teachers to tackle the gender imbalance. However, shortages witnessed in girls' take-up and their levels of success in STEM subjects during secondary education have continued to the present day (Bauer, 2017) even though girls have been shown to generally do better than boys in secondary education (Dury, Siy, & Cheryan, 2011). Also, there has been evidence of an understanding by many teachers of the fact that different students cope differently with the perceived challenges in STEM subjects (van Aalderen-Smeets & Walma van der Molen, 2018).

Reasons for increasing female participation in STEM such as 'achieving a fair and just society' and realising 'public and private benefits' (Smith, 2011 p.2) have been highlighted (e.g. Shin et al. 2016), with the need for a change in culture being portrayed as one way forward (Darmody & Smyth, 2005). References to large and small-scale interventions by parents, schools and teachers have been shown to influence and stimulate incremental beliefs about the malleability of females' capacities when choosing whether to study STEM subjects (van Aalderen-Smeets & Walma van der Molen, 2018). However, Shin et al. (2016) supported Rosenthal, Levy, London, Lobel & Bazile's (2013) belief that the impact of such interventions appeared to be short lived.

In terms of STEM career choices, Smith (2011) indicated that poor pay, a lack of career prospects and a failure to respond to the changing demands of an increasingly globalised STEM market were all persistent features responsible for female under-representation. Darmody & Smyth (2005, p.12) concurred stating that 'occupational segregation' found in advanced industrial societies remained a disappointing feature. This lack of females in STEM careers has also been exacerbated by low levels of recruitment into appropriate courses during tertiary education (Ceci et al., 2009; Dury et al., 2011; Shin et al., 2016; Smith 2011) and high levels of female dropout during pertinent degree courses (Shin et al., 2016; Smith, 2011; Sorby, 2009) even though in general at the age of 19 more women than men attend universities (Broecke and Hamed, 2008). Darmody & Smyth (2005, p.11) wrote about 'preferences and expectations' in terms of female STEM career choices at the end of secondary and tertiary education indicating the importance of family involvement, in particular a father's attitude and aspirations for his daughter which they highlighted as being influential, alongside the importance of an educational establishment's informal rather than formal sources of advice (Darmody & Smyth, 2005). Van Aalderen-Smeets & Walma van der Molen (2018) and others (e.g. Shin et al., 2016) indicated that career choices needed to be a careful matching process with the choice to study STEM being matched to the personal interests and aspirations of a student, if it was to be successful.

In 2005, Blickenstaff's analysis of literature concerning the lack of women in STEM identified nine reasons for the phenomena, although he believed that some points in the list had not been adequately proven. The nine reasons with additional support from more recent research, were as follows:

1. *Biological differences.* Early research indicated biological differences while more recent research largely refuted the earlier findings suggesting to Blickenstaff that if differences still existed it would be dangerous to emphasise them, as that could signal that no action was required, as research indicated that biological differences could not be overcome. He and others (e.g. Darmody & Smythe, 2005; Dury et al., 20011) also suggested that at times the only way a female could 'infiltrate' the STEM world was to act like a 'female male';
2. *Girls lack of academic preparation for a STEM career*. This reason Blickenstaff believed was open to criticism as research had indicated that the opportunities for academic preparation were provided, it was

just that they were rarely taken up. The other eight reasons in Blickenstaff's list providing some explanations for this lack of up-take;

3. *A lack of positive STEM attitudes and early experiences of STEM*. An absence of positive attitudes was well supported by both early research (e.g. Weinburgh, 1995) and in more recent times (e.g. van Aalderen-Smeets & Walma van der Molen, 2018). Although there remains strong disagreement over a dearth of positive early experiences of STEM being available (e.g. Roberts, 2016);
4. *Irrelevant STEM curricula*. Van Aalderen-Smeets & Walma van der Molen, (2018) added that girls found STEM lessons both difficult and boring;
5. *Pedagogy in STEM teaching favouring males*. This was reinforced by Dury et al. (2011) who considered STEM teaching to be masculine and incompatible with female needs and ways of learning; *'A chilly climate' in STEM classes* (Blickenstaff. p.372). This was also referred to as an unsociable environment by Dury et al. (2011), Barbercheck (2001) and Gherasim, Butnaru & Mairean (2013);
6. *An inherent masculine STEM epistemology*. In terms of the nature of the knowledge required to be learnt, which Dury et al. (2011) referred to as, male teachers being preoccupied with male-orientated technologies;
7. *Cultural pressure to conform to traditional gender roles*. This was upheld by Shin et al. (2016) who agreed that cultural pressure could discourage females from pursuing and persisting in both STEM subject matter and careers;
8. *An absence of female role models*. This has been a recurring theme throughout the literature and one that is addressed in Section 3 of this paper.

In terms of gender differences in the ways that people learn highlighted in Blickenstaff's list above, various researchers worldwide have discussed possible causes (e.g. Feingold, 1994; Pomerantz, Altermatt, & Saxon, 2001). Gurian & Stevens, (2004) indicated a disconnect between teaching practice and the needs of male and female brains, while others have discussed the effect of various personality traits (e.g. Feingold, 1994; Ruble, Greulich, Pomerantz & Gochberg, 1993) and that such differences remain robust across cultures (Costa, Terracciano, & McCrae, 2001; Gurian & Stevens, 2004). Samuelsson & Samuelsson (2014) highlighted a plethora of internal and external contextual factors, while Gurian and Stevens (2004) discussed structural and functional brain differences that many believed profoundly affected human learning while they agreed with others that recognising such differences could lead to the identification of solutions to the many challenges experienced in the classroom.

Smith (2011) suggested that in terms of STEM learning the root of the problem lay in poor quality STEM education which she and others (Fraser, 2014; Sorby, 2009) believed was partially caused by inadequate training of STEM teachers. This she indicated led to negative attitudes towards STEM by primary school teachers who lacked specific STEM skills, which then caused students problems when choices had to be made during secondary education. At tertiary level Sorby (2009) reported specifically on a lack of cognitive skills required for engineering. She signposted, for example, robust gender differences in 3-D rotation abilities that favoured males, although her research overturned what she considered a false belief that one was either 'born with or not' (p.478) such skills as her research indicated that these skills could be improved through practice with a greater positive impact on female rather than male students.

Many authors referred to the importance of psychological factors when considering the reason for female under-representation in STEM. Van Aalderen-Smeets & Walma van der Molen (2018) stressed that malleability of intelligence was an important factor. They suggested that those holding entity theories of intelligence were more susceptible to internalising gender stereotypical beliefs which then negatively impacted upon school subject optional choices and therefore career choices, while those holding incremental beliefs were affected less as they believed they could overcome gender disadvantages with hard work.

Other authors referred to further psychological factors that could negatively affect females' attitudes towards STEM. Factors such as: expectancy in terms of goals and motivation (Morgenroth, Ryan & Peters, 2015); the impact of natural aptitude and ability that were self-perpetuating if left unchallenged (Darmody & Smyth, 2005); a lack of interest and negative attitudes (van Aalderen-Smeets & Walma van der Molen, 2018); self-doubt (Fraser, 2014) and closely related, a lack of confidence (Cameron & Hayde, 2014) and self-efficacy (van

Aalderen-Smeets & Walma van der Molen, 2018); a lack of 'belongingness' and insecurity (Morgenroth et al., 2015; Shin et al., 2016).

Also, signposted as significant has been the negative effect of stereotyping. Darmody & Smyth (2005) referred to female self-stereotyping, while the issue of 'stereotype threat' that has been shown to affect many females in a STEM context (Bages, Verniers, Martinot, 2016; Ceci et al., 2009; Collins, 2009; Dury et al., 2011; Morgenroth et al., 2015; Stroessner & Good, nd.; Wright, 2018). Shin et al. (2016) and van Aalderen-Smeets & Walma van der Molen (2018) indicated that stereotypical beliefs were stronger in females than males and were exacerbated by social class (Darmody & Smyth, 2005). Shin et al. (2016) referred to 'cultural stereotyping' illustrating this with an example from their data, indicating that only gifted, European/US white males were successful in STEM, while Darmody & Smyth (2005) referred to rural, conservative, schools where stereotypical beliefs were more entrenched than in town and city schools. A longer discussion of these important issues causing the under-representation of females in STEM is beyond the scope of this paper although many of the factors already mentioned, impinge upon the effectiveness of role models and are discussed in the next section of this paper.

3. ROLE MODELS

Role models mean different things to different people (Casserly, 2010). Morgenroth et al., (2015) suggested that role models had three distinct functions as: a behavioural model; a representation of the possible; an inspiration. There have also been those who believed that their function was as a mentor (Collins, 2009; Cameron, 2014; Fraser, 2014). However, all writers have signalled their agreement concerning the usefulness of role models in regards of motivating others, and pertinent to this paper, their efficacy in encouraging females in under-represented situations to believe that their goals were achievable (Cameron & Hayde, 2014; Drury et al., 2011; Fraser, 2014; Shin et al., 2016).

The importance in terms of what a role model represents has been shown to be key. Successful role models tend to come from domains or groups to which the aspirant belongs (Lockwood & Kunda, 1997). These include groups such as: family networks; those in the same educational or work environments; those in similar socio-cultural situations (Ceci et al., 2009; Darmody & Smyth, 2005; Morgenroth et al., 2015). In my case the two role models that inspired me were from my educational environments. They were a female art and craft teacher during my schooldays and a male lecturer from when I was a student studying furniture design. These teacher role models were both excellent craftsmen and I was inspired by their ability and encouraged to develop not only craft skills but also a thirst for new knowledge, an appreciation of working with materials and a need for accuracy in all that I did, while still allowing me space to grow, make my own mistakes and be creative and innovative. They helped me believe that I could meet all challenges head-on and that through hard work I could achieve whatever goals I set myself. Their example encouraged me to try to achieve excellence in all that I did. My family network was extremely supportive of my ambitions and proud of my successes. They even bought me my own Meccano set. However, neither of my parents could act as a practical STEM role model, as their careers were far removed from STEM, although interestingly enough my much younger brother went on to become a civil engineer.

The literature concerned with highlighting attributes of successful role models has supported my understanding of pertinent characteristics. Authors have variously described role models as needing to be: motivating (Casserly, 2010; Cameron, 2014, Morgenroth et al., 2015); attainable, otherwise the aspirant may feel demoralised or incompetent in comparison to a 'superstar' (Bages et al, 2015; Lockwood & Kunda, 1997; Shin et al., 2016); relevant, indicating that if not relevant by not being in the same field, then the person being inspired would just be 'proud' to be associated with the superstar without that positively affecting their motivation to succeed in their own field (Bages et al., 2015; Lockwood & Kunda, 1997; Morgenroth et al., 2015); inspirational, in terms of being inspired by, or inspired to (Cameron, 2014; Fraser, 2014; Lockwood & Kunda, 1997; Morgenroth et al., 2015); desirable, suggesting that the aspirant had a shared sense of 'group membership' (Morgenroth et al., 2015) and therefore a sense of 'belonging' (Rosenthal et al., 2013, p.470); compatible, so that the aspirant was able to contradict the stereotype of gender incompatibility (Rosenthal et al., 2013); similar in social standing, which researchers have linked to interests and values (Ceci et al., 2009; Lockwood & Kunda, 1997; Morgenroth et al., 2015); confident in themselves and their ability to achieve their ambition (Fraser, 2014). It has also been shown to be important that a role model's success could be explained by effort rather than innate ability or talent (Bages et al, 2015). In terms of being a role model myself, I hope that throughout my career I have been seen to possess some of these positive characteristics, with my passion for all things STEM related and my ambition to pass on that passion to others being a visible aspect of my persona.

Research has indicated that it is not just the type of role model that is important in the relationship. A role model is only likely to inspire if the aspirant already has a well ignited spark of interest in the role model's field of expertise. The aspirant's own characteristics are also important. If Aspirants believe that their intelligence and ability are stable, controllable and malleable then they will believe that the success achieved by a role model is attainable (Morgenroth et al., 2015). In contrast, if an aspirant believes that intelligence is fixed and unchangeable then they will believe that the role model's success is not achievable (Bages et al. 2015). They must also believe in self-enhancement, having trust in their own capabilities (Lockwood & Kunda, 1997) and that even if the goal is not achievable immediately, that there is a possibility of attaining success in the future (Lockwood & Kunda, 1997). All these attributes need encouragement to help overcome a lack of confidence and sense of pessimism witnessed amongst females within a STEM context.

Previous research has indicated that the gender of a role model is also important (Bages et al. 2015; Darmody & Smyth, 2005; Dury et al., 2011). In the case of female aspirants, inspirational female role models and not male role models have proved successful (Rosenthal et al., 2013). Unfortunately, research data indicates that there have been, and still are a lack of suitable female role models (Dury et al. 2011; Fraser, 2014) and a shortage of women taking to public platforms to share their journeys (Wright, 2018). This is self-perpetuating and cyclical. If there are not many females studying STEM subjects in schools and taking up STEM careers then there will not be many who can become role models encouraging the next generation of young people to take up STEM careers and in turn become the next influential role models.

4. CONCLUSION

> 'Conformity to social expectations, gender stereotypes, gender roles and a lack of role models continue to channel girls' career choices away from STEM fields' (Noonan & Laffarge, 2017).

The above quotation admirably sums up the conclusions to this paper concerning woman's under-representation in STEM, the part role models have played in the past and whether or not we still need them today. Having been in a privileged position, as a female teaching a STEM related subject for the past six decades, I hope that I have acted as a positive role model throughout that time. I have certainly tried to encourage all the females that I have come into contact with to have confidence in their ability to study and take up careers in various aspects of STEM. I have relished helping them to develop their capability and achieve success and above all to enjoy and become passionate about what they have learnt. STEM needs as many female advocates as possible if we are to overcome the problem of female under-representation. If we do not, there will continue to be serious consequences for STEM and it will remain an area of global concern. So, the answer is 'Yes' we still need relevant, genuine, confident and yet humble, successful, passionate, encouraging and generous role models today, and for the foreseeable future.

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