Gender Equity in STEM: Addressing the Disparities

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Abstract

Despite similar achievement levels, females continue to be underrepresented in Science, Technology, Engineering, and Mathematics (STEM) disciplines. Given the strategic importance of these for New Zealand's future, ensuring females have equitable access to education and careers in these sectors is vital for upholding diversity and equality. This literature review examines current research on gender disparities in STEM, and identifies three key contexts of gender interest in STEM: developing, maintaining, and retaining. These contexts are aligned to the primary, secondary, and tertiary, education sectors, within which current research on self-concept and self-efficacy, social belongingness, and stereotypes are investigated. A key finding of the importance of physical science exposure and experience for later female vocational interest and retention is identified. This and other outcomes from the literature, provide evidence for potential tangible strategies to encourage increased gender uptake in STEM.

Keywords: *Gender, STEM, Self-concept, Self-efficacy, Achievement, Bias, Equity, Education.*

Introduction

The importance of science in enhancing and sustaining New Zealand's future has been shown through the development and implementation of current New Zealand Government initiatives such as the National Statement of Science Investment 2015 - 2025 (NSSI) whose vision is "a highly dynamic science system that enriches New Zealand, making a more visible, measurable contribution to our productivity and wellbeing through excellent science" (Ministry of Business Innovation and Employment, 2015, p.7). However, despite New Zealand's national push for science, technology, engineering, and mathematics (STEM), women continue to be underrepresented in many of these academic and vocational areas (Ministry of Education, 2016).

A literature review into educational gender differences was commissioned by the Ministry of Education in 1999 to investigate mounting concerns of falling academic achievement rates in boys from 1989-1999 (Alton Lee & Praat, 2000) Interestingly, within science however no significant differences in gender achievement was evidenced at the primary education stage, however by the beginning of secondary school significant gender differences in favour of boys was evidenced (Alton Lee & Praat, 2000). Furthermore, girls attitudes towards science showed decline consistent with international trends (Alton Lee & Praat, 2000) .

No updated report has been commissioned since 2000, but current international testing data from PISA (Programme for International Student Assessment) and TIMSS (Trends in International Mathematics and Science Study) shows that there are no significant differences in average science achievement between genders (Ministry of Education, 2017). Therefore, the lack of females in certain STEM disciplines such as the physical and mathematical sciences, engineering, and computer science (Ministry of Education, 2016) cannot be explained by lower achievement levels. A review of current literature provides insight in understanding gender disparities across the primary, secondary, and tertiary sectors.

Developing Interest: Self-Concept and Achievement

Differences persist in early science exposure between the genders, with research from Jones, Howe, and Rua (2000) demonstrating that by sixth grade, boys are more likely to have had higher extra-curricular exposure to physical sciences whereas, in contrast, girls were more likely to have had biological sciences experiences. Prediger (1982) surmised that the RIASEC vocational framework which measures six interest types; Realistic, Investigative, Artistic, Social, Enterprising, and Conventional, has two fundamental dimensions of *data-ideas* and *people-things*. Using these dimensions, Lippa (1998) investigated the differences between gender vocational interests in ideas-data and people-things subgroups. Men were shown to have a greater interest in working with things, compared to women whose preference was people based professions (Lippa, 1998). Whilst some research maintains there are minimal differences between the genders (Hyde, 2005), statistical meta-analyses such as that by Su, Rounds, and Armstrong (2009) continue to assert innate differences in the people-things dimension as a factor in gender vocational interest disparities.

Research by Leibham, Alexander, and Johnson (2013) aimed to further investigate links between early science interest in preschool and later achievement levels at age eight. Interestingly, early interest was shown not to be a factor in predicting later science achievement for boys, however it was related to later achievement levels for girls (Leibham et al., 2013). Furthermore, whilst there were no gender differences in overall achievement levels, subsequent analysis did show that boys achieved higher in physical science and girls higher in biological science (Leibham et al., 2013). Therefore, as discussed by Jones et al. (2000) early exposure of girls to physical science may increase interest and thus achievement levels, and the importance of doing so is that "from the perspective of power, equity, and financial resources, encouraging girls in the physical sciences can open doors that lead away from traditional lower paying jobs held by women" (p. 189).

Despite differences in early preschool interest, Leibham et al. (2013) found no difference in science self-concept between genders at age eight whereby they defined self-concept as "a multidimensional concept that reflects one's perceptions of relative competence in various domains including social, cognitive, and physical activities" (p. 577). Whilst there were no differences overall, Leibham et al. (2013) did conclude that girls with early interest in science had a higher science self-concept at age eight than boys with the equivalent initial interest. Self-concept, however, was not shown to have a mediating effect on the relationship between early science interest and later achievement, and they therefore concluded that early interest in science raises achievement levels for girls (Leibham et al., 2013). The effects of interest on gender equity in STEM is a common research theme in much of the literature.

Maintaining Interest: Self-efficacy and Social Belongingness

Vocational interest remains a pivotal aspect throughout secondary education for encouraging gender equity in STEM. The leaky pipeline metaphor is used within the literature to describe the phenomenon of high initial student interest in STEM, and the characteristic loss of interest amongst some students, especially women (Sadler, Sonnert, Hazari, & Tai, 2012). As previously identified an early interest in science in girls can be a predictor of higher later achievement (Jones et al., 2000; Leibham et al., 2013), therefore if achievement is equal or higher than boys (Ministry of Education, 2017) we must next examine potential mediating factors which may be affecting the differences in gender vocational interest.

Sadler et al. (2012) identified students shifts in STEM attitudes in secondary school and related vocational interests. In a 6,860 cohort of American students, male STEM vocational interests remained stable throughout secondary education from 39.5% beginning to 39.7% finishing high school (Sadler et al., 2012). In compararison, female student STEM vocational interests were significantly lower and displayed higher attrition from 15.7% at the beginning, reducing to 12.7% by the end of high school (Sadler et al., 2012). Interestingly, retention rates of STEM vocational interest were shown to be higher in females with initial physics or engineering interest and lower in males with biology or earth/environmental science (Sadler et al., 2012), which conflicts with current early science exposure whereby the majority of females had more exposure to biology as outlined by Jones et al. (2000). The links between the retention of females in STEM and early science education were identified by Sadler et al. (2012) as a potential strategy for raising the number of women in later STEM careers.

Research by Tellhed, Bäckström, and Björklund (2017) concludes that consideration of self-efficacy and social belongingness are important in explaining gender differences in interest between STEM and HEED (Health care, Elementary Education, and the Domestic spheres). Tellhed et al. (2017) argue that current literature focuses on levels of participation of women in STEM with little consideration given to the opposing underrepresentation of men in HEED, and in their research they aim to contribute to the study of both disciplines. Self-efficacy is a similar term to self-concept in that both relate to an individual's competence beliefs; however, self-efficacy has more specificity surrounding a learning area or task (Leibham et al., 2013; Tellhed et al., 2017). Although Leibham et al. (2013) concluded their research showed no evidence for self-concept as a mediator in science interest and achievement in elementary school, new evidence from Tellhed et al. (2017) in Sweden suggests that self-efficacy does in fact act as a mediator for STEM interest in secondary school students.

Furthermore, Tellhed et al. (2017) found that social belongingness was a mediator for both STEM and HEED interest, though the effect of this was strongest on STEM. They argued that social belongingness was particularly important at a high school student age level because student expectations are that they will experience greater social belongingness from their own gender and thus this helps to explain why males are generally more interested in STEM and females in HEED (Tellhed et al., 2017). This was an important novel finding from their research which indicates more consideration may be needed for encouraging more women in to gender minority vocations.

Retaining Interest: Society, Stereotypes and Bias

Females currently outnumber males in attainment rates of undergraduate degrees in New Zealand (Ministry of Education, 2016) but gender disparities remain in the choices of major subject within STEM. These numbers reflect the current literature on differences in gender vocational interest and STEM experiences (Jones et al., 2000; Lippa, 1998; Sadler et al., 2012; Tellhed et al., 2017). Latest available statistics show that of the bachelor degrees conferred on domestic New Zealand students in 2015, males outnumbered females in engineering, mathematics, and computer science, whereas females outnumbered males in health (with particularly significant disparity in nursing) and biological sciences (Ministry of Education, 2016). Ratios of gender within these major subjects supports international trends of differential STEM and HEED interests.

Diekman, Clark, Johnston, Brown, and Steinberg (2011) argue for a goal congruity perspective where they cite evidence that females are more likely to value communal societal goals, such as working with people, which conflicts with the notion that STEM careers do not facilitate communal goals. These STEM goal affordance stereotypes were, unsurprisingly, therefore shown to be stronger in females than males (Diekman et al., 2011). Furthermore, there was evidence for a causal link between the goal congruity model of communal goals and goal affordance stereotypes and STEM interest, by statistically significant results which demonstrated that by increasing communal goal values, STEM vocational interest was decreased amongst participants, whilst there was no effect on alternative career interest (Diekman et al., 2011). It is important to note however that this causal link was only shown in the small sample size of 64 participants.

Whilst the goal congruity perspective demonstrates links between communal goals and goal affordance stereotypes to STEM vocational interest, the authors highlight that their research should be seen as a contribution to the field and that "a focus on communal processes should not supplant a focus on other critical variables, such as self-efficacy, experience in math and science, or prejudice against women in these fields" (Diekman et al., 2011, p. 913) Furthermore, with consideration to raising levels of women in STEM careers, thought must be given not only to recruitment but also retention (Diekman et al., 2011).

Recent research on self-efficacy, interest and experience have been shown to influence STEM gender interest (Diekman et al., 2011; Jones et al., 2000; Lippa, 1998; Sadler et al., 2012; Tellhed et al., 2017) but the effects of societal influence, such as persistent science and gender stereotypes, has had reduced research. Research has shown that when there are strong heteronormative gender-science stereotypes, females tend to have lower science identification and vocational interest whereas males display higher science identification and vocational interest when the same gender-science stereotypes are present (Cundiff, Vescio, Loken, & Lo, 2013). Cundiff et al. (2013) showed that implicit stereotyping lead to lower rates of females' intention to persist in science education, however this result was offset when science identity was accounted for. They suggest that strong identification with science mediates the effect of implicit stereotyping and the intent to persist (Cundiff et al., 2013). Interestingly, gender identity did not have the same mediating effect on implicit stereotyping in either gender and limited results for a potential mediating factor for males self-reported stereotyping where self-report is personal identification of agreement with stereotypes (Cundiff et al., 2013).

There is also evidence to support that gender-science stereotypes may not only influence undergraduate choices (Cundiff et al., 2013) but may also lead to implicit bias higher within tertiary science faculties (Moss-Racusin, Dovidio, Brescoll, Graham, & Handelsman, 2012). In a sample of university professors of physics, chemistry, and biology from the United States of America (USA), faculty members of both genders displayed implicit bias during a double-blind study where faculty members were presented with applications for a laboratory manager job, the applications had identical credentials whereby the only variation was gender name (Moss-Racusin et al., 2012). Results showed the male application was more likely to be hired, be offered greater career mentoring and a higher starting salary than the equivalent female applicant (Moss-Racusin et al., 2012). Thus for Moss-Racusin et al. (2012) this raised the concerns about the potential negative consequences of faculty bias in the retention of female graduates in STEM post-undergraduate education.

Limitations

Lack of contemporary empirical New Zealand based research on gender equity in STEM remains a limitation; however, current tertiary statistics (Ministry of Education, 2016) support the same trends in gender vocational data which has been identified in the, mostly, USA-centric literature. It is also important to note, that in many of the studies the results showed only the correlation between variables rather than causation, which suggests there may remain unidentified mediating factors influencing the data (Cundiff et al., 2013; Diekman et al., 2011; Tellhed et al., 2017). The methodologies used by researchers, such as retrospective studies (Sadler et al., 2012) or the use of parental survey (Leibham et al., 2013), have the potential to affect the ability to obtain accurate data because answers may be unintentionally skewed and therefore this should also be taken in to consideration.

Furthermore, participants in samples may not reflect the total diversity within populations. For example, many of the studies had samples in which the majority of participants were identified as Caucasian (Cundiff et al., 2013; Diekman et al., 2011; Leibham et al., 2013) and often from urban geographical areas. Considerations of socioeconomic status should also be considered as a potential limitation, such as that identified by Leibham et al. (2013).

Future Research

As previously identified, a current lack of participant diversity identifies potential areas for future research. Diverse samples may include more research on gender interest in STEM within ethnic minority groups, or students from low socioeconomic groups. Furthermore, currently the focus remains on gender as a dichotomous variable rather than a continuous spectrum, therefore increased consideration on a wider range of gender identity experiences in STEM may help to contribute to the current body of literature. Cundiff et al. (2013) also suggests research on strong 'gender-science' stereotypes and the potential effects in the underrepresentation of females in STEM.

Conclusion

The issue of continued underrepresentation of females in traditionally male dominated STEM disciplines is decidedly complex and challenging. As educators are facing increasingly diverse classrooms, consideration of limiting factors in achieving equitable access for minorities, such as females in STEM, is crucial for ensuring inclusive education. A common recurring theme was the importance of motivating STEM interest in girls, particularly at an early age. Ensuring equitable access and exposure to physical science may set students on a pathway which enables them to successfully navigate and circumvent the leaky pipeline. As educators, consideration must therefore be made on the potential strategies and pedagogies of how to effectively implement and enact this in the classroom.

Furthermore, there was an awareness throughout the literature reviewed, that an obstacle to achieving gender equity in STEM is not only the ability to recruit more women but also, crucially, how to retain them in the field. To be able to effectively do this the literature suggests it will likely require a societal shift in our embedded stereotypes and practices, as inherent biases remain unchallenged. Examining assumptions and remaining open to reflection of our own values and beliefs, may help to mitigate potential unexamined stereotypes or bias.

Although the issue is complex, the literature highlights the potential areas for intervention and action, which educators may be able to enforce to make meaningful change in STEM uptake rates. Considering the equal science achievement levels in assessment between genders, encouraging self-concepts and promoting STEM as a viable career pathway for females should be considered for beginning to address the current vocational disparities.

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