Science, Technology, Engineering and… Masculinity? How psychological theory can help understand and improve the gender gap within STEM subjects

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Abstract

The under-representation of females in science, technology, engineering and mathematics (STEM) is a key educational issue which warrants discussion. This paper explores the gender gap in STEM education from a psychological perspective, drawing on Social Learning Theory and Social Identity Theory to explain the phenomenon. This paper highlights that same-sex STEM role models are an important source of learning which are missing from many females' early experiences. However, it is concluded that the in-group male prototype and unwelcoming social environments found in STEM education, threaten females' social identity and significantly impact on persistence in STEM education. In evaluating interventions to encourage female participation in STEM education, it is recommended that future intervention targets both male and female students and focuses on mixed-gender environments to reflect the reality of studying STEM subjects.

Keywords

female, gender, education, STEM, social learning theory, social identity theory, intervention

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Introduction

There is a persistent and significant gender gap within the subjects of science, technology, engineering and mathematics (STEM), with recent statistics revealing that females make up just 22% of the United Kingdom's core STEM workforce (WISE, 2018a). Furthermore, STEM subject statistics display that while females represent 48% of GCSE STEM subject entries and outperform males in most GCSE STEM subjects (WISE, 2018b), females represent just 24% of core STEM subject graduates (WISE, 2018c). The educational statistics suggest that the gender disparity in STEM fields manifests in education with the number of females studying STEM subjects decreasing the higher the level of education.

The absence of females in STEM subjects and subsequently in the STEM workforce is concerning both for the individual and society, impacting global competitiveness, social justice and inclusion (Greenfield et al., 2002). Hunt et al. (2016) highlight the economic benefits of closing workforce gender gaps, proposing that if the gaps are narrowed, 150 billion pounds could be added to the UK GDP forecast by 2025. In addition, Hunt et al. (2016) estimates that 35% of the increase in UK GDP could come from females securing careers in more productive fields such as those within STEM. Consequently, there is a strong rationale for identifying how to address the gender gap and effectively encourage more females to study STEM subjects.

From a psychological perspective, this short practical piece explores, and attempts to explain why fewer females elect to study STEM as they progress through the education system, an issue that is often referred to as the leaking STEM pipeline (Blickenstaff, 2006; Hurk, Meelissen and Langen, 2019). Two key psychological theories, Social Learning Theory (Bandura, Ross and Ross, 1961) and Social Identity Theory (Tajfel, 1982), will be drawn upon to provide an explanation for the phenomenon. A critical evaluation of interventions that have been used to encourage more females to study STEM to date will also be discussed.

Social Learning Theory

Social Learning Theory offers an explanation as to why females do not elect to study STEM, placing emphasis on two key factors, the reinforcement of stereotypical gender roles and the influence of same-sex role models (Bandura, Ross and Ross, 1961; Perry and Bussey, 1979). Social Learning Theory (Bandura, Ross and Ross, 1961) suggests that gender identity is a set of learned behaviours which are formed through observing and imitating role models. In developing sex roles and gender identity it has been found that children are more likely to imitate the behaviour of a same-sex role model (Perry and Bussey, 1979). Furthermore, children can receive reinforcement for their imitation of same-sex role models, this can be vicariously as the child imitates

behaviour which they observe being rewarded or directly through praise and acceptance (Helgeson, 2016). Thus, females imitate female role models, experiencing both vicarious and direct reinforcement for the imitated behaviour, which forms their gender identity.

The usefulness of Social Learning Theory (Bandura, Ross and Ross, 1961) in explaining the STEM subject gender gap is demonstrated in research confirming that parents' model and reinforce gender roles for children. Croft et al. (2014) investigated how observed gender differences in parental domestic labour impacted children's future aspirations. They found that mothers' gender role beliefs predicted their daughters' gender role beliefs and when families had a more egalitarian approach to domestic labour, daughters were more interested in less stereotypical occupations. Moreover, research from Leaper (2002) observed parent-child pairs playing with stereotypical toys and found that parents displayed lower levels of affiliation and assertion when playing with stereotypical masculine toys with their daughters and stereotypical feminine toys with their sons. Both Croft et al.'s (2014) and Leaper's (2002) research demonstrates that parents model gender roles and reinforce gender behaviour through interactions with their children. This highlights the usefulness of Social Learning Theory in considering why females do not elect to study STEM subjects, suggesting that if parents fail to model and reinforce positive behaviours and attitudes concerning STEM subjects, females will not learn that engagement in them is appropriate behaviour for their gender.

Social Learning Theory explains why females do not elect to study STEM subjects through its identification of the importance of same-sex role models (Perry and Bussey, 1979). The underrepresentation of females in the STEM workforce (WISE, 2018a) highlights that there are limited same-sex role models for females to learn that engagement in STEM subjects is acceptable behaviour for their gender. Furthermore, RS components (2019) analysis of teacher gender within the top UK universities found that females make up just 16% of the maths teaching faculty and 17% of the science teaching faculty, demonstrating a clear lack of female role models in higher education. The influence of female teachers on female students subject choice has been examined, Bottia et al. (2015) found that female students who attended high schools with higher numbers of female STEM teachers were more likely to major in a STEM subject at college. Similarly, Herrmann et al. (2016) found interaction with a female role model in STEM study resulted in lower female withdrawal rates. O'Brien et al. (2017) also highlight the significance of female role models, finding that girls' interests in STEM subjects can be positively influenced by as little as one day's exposure to a female role model, and when girls are encouraged to explore why they favour female role models, the positive impact can be increased further. This research demonstrates that Social Learning Theory can explain why females may not elect to study STEM

subjects; due to a lack of same-sex role models and the reinforcement of stereotypical gendered behaviour.

Despite the strong evidence supporting Social Learning Theory and its application to the gender gap in STEM subjects, others have suggested alternative explanations. For example, Lewis et al. (2016) argue that STEM studying involves complex social environments, therefore, the impact of female belonging in STEM social contexts on their persistence to study STEM subjects needs to be considered. These findings are strengthened with further research demonstrating that female students' self-esteem and a sense of belonging in STEM subjects are significant factors that influence females' decisions to continue studying STEM subjects (McPherson, Banchefsky and Park, 2018). Furthermore, Lewis et al. (2017) and Rainy et al. (2018) found that females displayed lower levels of self-esteem and a sense of belonging in STEM fields than males, which predicted their intent to pursue STEM study.

Social Learning Theory cannot fully explain why females do not elect to study STEM subjects as they progress through education. Females do not just passively observe and imitate role models, there are other influences, like their beliefs, belongingness and self-esteem which are all impacted by the social environments in which they study (e.g. Lewis et al., 2016; Lewis et al., 2017; Rainy et al., 2018). The expectation that learners are passive and the lack of acknowledgement of cognitive processes are critiques echoed in the literature, demonstrating limitations in using Social Learning Theory as a singular explanation for gender disparity in STEM subjects (Ó Siochrú, 2018).

Social Identity Theory

Social Identity Theory (Tajfel, 1982) is an alternative theory to explain why females do not elect to study STEM subjects as they progress through the education system. It considers females' experiences within STEM study environments and highlights that females may not have positive STEM study experiences due to the impact of social group processes within STEM subjects. Social Identity Theory argues that social categorisation leads to the formation of in-groups and out-groups and membership to a group forms a person's social identity, which defines what it means to be part of the group and holds information of expected norms, values and attitudes of an in-group prototype (Tajfel, 1982).

STEM subjects are studied predominantly by males and therefore, males fit a stereotypical prototype of a STEM student. Females may not categorise themselves as part of the in-group in STEM environments, suggesting that building a STEM identity is a challenge for females. Nosek, Banaji and Greenwald (2002a) found that social identity can prevent female engagement in STEM subjects, due to the conflict

between multiple social identities. They found that females struggled to identify with both their female social group and a maths social group, due to stereotypical associations between maths and males and their female social identity.

Dasgupta and Spout's (2014) research exploring females' sense of belonging and self-esteem in STEM study evidences the significant impact of a male STEM in-group prototype on females' intentions to study a STEM subject. They found that a key barrier to females' STEM interest in emerging adulthood was feeling like a misfit in STEM classes. There are various explanations for why females may feel like a misfit when studying STEM subjects. Good, Rattan and Dweck's (2012) research, explains that sense of belonging and self-esteem in mathematics study is hindered in females due to a combination of believing that mathematics ability is fixed and the stereotypical belief that women are less able than men at mathematics. This research demonstrates the usefulness of Social Identity Theory in explaining why females may not elect to study STEM, underlining that females do not identify with the STEM in-group due to the STEM in-group prototype being stereotypically viewed as male. A lack of STEM identity can result in a lower sense of belonging and self-esteem, both of which are identified in the literature as influencing females' decisions to study STEM (Lewis et al., 2017; Rainy et al., 2018).

Females decisions to study STEM subjects are not only influenced by explicit stereotypical beliefs, there is research evidencing that gender stereotyping is apparent on an unconscious level in both males and females (Nosek et al., 2002b; Hill, Corbett and Rose, 2010). Van Aalderen-Smeets and Walma Van der Molen (2018) argue that whilst some females explicitly reject the stereotype that females are less able than males in STEM subjects, it may be still held on an unconscious level and thus influence their decisions to study STEM subjects. Nosek et al., (2002a) found that female college students' negative attitudes towards STEM subjects were related to their implicit stereotypical views that STEM subjects are male. Research which specifically explores the impact of implicit, gender-science stereotypes on the career decisions of female students, found that those with stronger implicit gender-stereotypes held weaker science career aspirations (Cundiff et al., 2013). The research discussed demonstrates that the influence of gender stereotypes on females decisions to study STEM subjects is a complex area and intervention to encourage females to study STEM subjects should not rely on self-report methods alone, unconscious bias must be acknowledged. However, approaches to eliminating unconscious bias remain in debate with concerns that unconscious-bias training may have a negative impact, there is a demand for further research in this area (Devlin, 2018).

Social Identity Theory states that the self-esteem derived from social group membership motivates individuals to strengthen their membership. Group

membership can be strengthened by exaggerating the differences between the in-group and out-group, which includes negative stereotyping and the exclusion of those who do not meet the in-group prototype (Hogg and Vaughan, 2011). Therefore, Social Identity Theory importantly considers the influence of social inter-group behaviours and the influence of in-group behaviour on out-groups is supported in literature. For example, Riegle-Crumb and Morton (2017) found that females in STEM study are exposed to male peers with strong gender and STEM stereotypes, resulting in females not electing to study STEM subjects at college. Similarly, Leaper and Brown (2008) documented that female students experience sexist comments from their male peers about their STEM abilities. The negative impact of experiencing sexism in STEM study is established in Logel et al.'s (2009) research which found that interactions with males who held strong gender stereotypes and behaved in sexist ways in engineering study resulted in females experiencing social identity threat.

Social identity threat is an important concept to consider as it highlights that when negative evaluations are made about social groups, members feel threatened (Mavor, Platow and Bizumic, 2017). When investigating the impact of social identity threat in more depth, Major and O'Brien (2005) argued that it results in individuals disengaging self-esteem from threatening fields. Therefore, research demonstrates that the male in-groups in STEM subjects draw on stereotypes and evaluate females negatively as a social group, which threatens females' social identity, resulting in their lack of self-esteem and consequently removal from the study of STEM subjects.

To conclude, Social Learning Theory (Bandura, Ross and Ross, 1961) does offer a useful explanation as to why females do not elect to study STEM, highlighting that positive STEM role models, particularly same-sex role models, are an important source of learning which are largely missing from most females' experiences. However, Social Learning Theory may not fully explain the gender disparity in STEM subjects because it assumes learner passivity and overlooks cognitive processes and the impact of females' self-esteem and belongingness in STEM study. Consequently, Social Identity Theory (Tajfel, 1982) has been identified as offering a stronger explanation, as it can account for why females may remove themselves from STEM study, highlighting that the social environments in STEM study are not welcoming for females due to STEM in-group prototypes being viewed as male. Furthermore, male STEM in-group attitudes and behaviours in STEM study environments can threaten females' social identity which reduces self-esteem and a lack of belongingness, resulting in females removing themselves from STEM pipelines due to not holding a strong STEM identity (Kim, Sinatra and Seyranian, 2018). It is important that females can experience group membership and a shared social identity within STEM study to support their self-esteem and belongingness and subsequently their decisions to remain studying STEM subjects.

Interventions

Growing discussion and investigation into the STEM gender gap in education has resulted in the design and implementation of several interventions aimed at encouraging female participation and persistence in STEM subjects. A commonly used intervention is the provision of female mentors and leaders used to encourage and support female participation in STEM subjects. Dennehy and Dasgupta (2017) found that time spent with a female peer mentor increased female retention in engineering and Latu et al. (2013) suggest that successful female leaders can empower female students. However, both studies focus on an intervention for individual female students. Others, such as Lewis, Sekaquaptewa and Meadows (2019) critique an individualised approach, highlighting that STEM education contains high levels of group work and if both interventions and the approaches used to measure impact are individualised, then the significant influence of group work is disregarded.

Single-sex STEM workshops where females can experience STEM subjects without males is another key intervention used to encourage female interest and persistence in STEM study. Watermeyer (2012) measured the impact of a single-sex workshop on females' interest in STEM study and found that after the workshop 38% of female high school students found their interest in STEM subjects increased. However, some of the females did report negative feelings towards this single-sex programme, suggesting that it was sexist and that males should have also been able to participate. Legewie and DiPrete (2014) support this finding and highlight that single-sex extracurricular activities can reinforce and add to gender inequality in STEM subjects, as they model and demonstrate gender segregation to students.

Van Den Hurk, Meelissen and Van Langen's (2019) meta-review highlights that research on interventions to encourage interest and persistence of females in STEM subjects, focus on approaches aimed at only females. However, the importance of group work and female belonging in mixed gender STEM social groups highlights that this prevalent intervention approach may be problematic. The statistics demonstrate that the higher in education students progress the more male dominated STEM subjects become (WISE, 2018c), therefore, students need interventions which reflect the reality of studying a STEM subject and supporting them to build their social identity within a mixed-gender STEM groups.

Furthermore, interventions need to target both male and female students. For example, Lewis, Sekaquaptewa and Meadows (2019) provided mixed gender groups of students with a video which modelled STEM group work in a way that challenged STEM stereotypical roles. This study importantly used an approach which not only targeted female minorities in STEM subjects but provided an intervention designed to

change the behaviour of the whole group including males. The application of both Social Learning Theory and Social Identity Theory to the current gender disparity in STEM subjects, along with an evaluation of current interventions suggests that further research and intervention design which considers female belonging, and self-esteem in STEM social contexts is required to support female interest and persistence in STEM subjects.

References

Bandura, A., Ross, D. and Ross, S. A. (1961) Transmission of aggression through imitation of aggressive models. *The Journal of Abnormal and Social Psychology*, 63(3), pp. 575-582.

Blickenstaff, J. C. (2006) Woman and Science Careers: Leaky pipeline or gender filter? *Gender and Education*, 17(4), 369-386.

Bottia, M. C., Stearns, E., Mickelson, R. A., Moller, S. and Valentino, L. (2015) Growing the Roots of STEM Majors: Female Math and Science High School Faculty and the Participation of Students in STEM. *Economics of Education Review*, 45, 14–27.

Cheryan, S., Plaut, V. C., Davies, P. G., & Steele, C. M. (2009) Ambient belonging: How stereotypical cues impact gender participation in computer science. *Journal of Personality and Social Psychology*, 97(6), 1045-1060.

Croft, A., Schmader, T., Block, K. and Baron, A. S. (2014) The Second Shift Reflected in the Second Generation: Do Parents' Gender Roles at Home Predict Children's Aspirations? *Psychological Science*, 25(7), 1418–1428.

Cundiff, J.L., Vescio, T. K., Loken, E. and Lo, L. (2013) Do gender–science stereotypes predict science identification and science career aspirations among undergraduate science majors? *Social Psychology of Education*, 16, 541-554.

Dasgupta, N. and Stout, J. G. (2014) Girls and Women in Science, Technology, Engineering, and Mathematics: STEMing the Tide and Broadening Participation in STEM Careers. *Policy Insights from the Behavioral and Brain Sciences*, 1(1), 21–29.

Dennehy, T. C. and Dasgupta, N. (2017) Female peer mentors early in college increase women's positive academic experiences and retention in engineering. *Proceeding of the National Academy of Sciences*, 114(23), 5964–5969.

Delvin, H. (2018) Unconscious bias: what is it and can it be eliminated? *The Guardian* [online], 2 December. Available from: < https://www.theguardian.com/uk-

news/2018/dec/02/unconscious-bias-what-is-it-and-can-it-be-eliminated> (Accessed 2/8/2020)

Good, C., Rattan, A., and Dweck, C. S. (2012) Why do women opt out? Sense of belonging and women's representation in mathematics. *Journal of Personality and Social Psychology,* 102(4), 700-717.

Greenfield, S., Peters, J., Lane, N., Rees, T. and Samuels, G. (2002) *A report on women in science, engineering and technology for the Secretary of State for Trade and Industry* [online]. Available from: <http://image.guardian.co.uk/sys-files/Education/documents/2002/11/28/4408-DTI-Greenfield.pdf> (Accessed 22/10/2020)

Helgeson, V. C. (2016) *Psychology of Gender.* 5th ed. Oxon: Routledge.

Herrmann, S. D., Adelman, R. M., Bodford, J. E., Graudejus, O., Okun, M. A., and Kwan, V. S. Y. (2016) The effects of a female role model on academic performance and persistence of women in STEM courses. *Basic & Applied Social Psychology*, 38(5), 258–268.

Hill, C., Corbett, C. and Rose, A. (2010) *Why So Few? Woman in Science, Technology, Engineering and Mathematics* [online]. AAUW. Available from: <https://www.aauw.org/aauw_check/pdf_download/show_pdf.php?file=why-so-few-research> (Accessed 20/6/20)

Hogg, M. A. and Vaughan, G. M. (2011) *Social Psychology.* 6th ed. Essex: Pearson Education Limited.

Hunt, V., Dobbs, R., Gibbs, E., Madgavkar, A., Woetzel, J., Arora, S., Hong, W. and Krishnan, M. (2016) *The Power of Parity: Advancing Woman's Equality in the United Kingdom* [online]. McKinsey & Company. Available from: <https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Women%20matter/The%20power%20of%20parity%20Advancing%20womens%20equality%20in%20the%20United%20Kingdom/Power-of-parity-Advancing-womens-equality-in-the-United-Kingdom-Full-report.ashx> (Accessed 27/8/2020)

Hurk, A., Meelissen, M. and Langen, A. (2019) Interventions in education to prevent STEM pipeline leakage. *International Journal of Science Education*, 41(2), 150-164.

Kim, A. Y., Sinatra, G. M., and Seyranian, V. (2018) Developing a STEM Identity Among Young Women: A Social Identity Perspective. *Review of Educational Research*, 88(4), 589–625.

Latu, I. M., Mast, M. S., Lammers, J. and Bombari, D. (2013) Successful female leaders empower women's behavior in leadership tasks. *Journal of Experimental Social Psychology*, 49(3), 444–448.

Leaper, C. (2000) Gender, affiliation, assertion, and the interactive context of parent–child play. *Developmental Psychology*, 36(3), 381-393.

Legewie, J. and DiPrete, T. A. (2014) The High School Environment and the Gender Gap in Science and Engineering. *Sociology of Education*, 87(4), 259-280.

Lewis, K. L., Stout, J. G., Pollock, S. J., Finkelstein, N. D., and Ito, T. A. (2016) Fitting in or opting out: A review of key social-psychological factors influencing a sense of belonging for women in physics. *Physical Review Physics Education Research*, 12, 1-10.

Lewis, K.L., Stout, J.G., Finkelstein, N.D., Pollock, S.J., Miyake, A., Cohen, G.L. and Ito, T.A. (2017) Fitting in to move forward: Using a belonging framework to understand gender disparities in persistence in the physical sciences, technology, engineering, and mathematics (pSTEM). *Psychology of Women Quarterly*, 41(4), 420-436.

Lewis, N. A., Sekaquaptewa, D. and Meadows, L. A. (2019) Modeling gender counter-stereotypic group behavior: a brief video intervention reduces participation gender gaps on STEM teams. *Social Psychology of Education*, 22(3), 557-577.

Logel, C., Walton, G. M., Spencer, S. J., Iserman, E. C., von Hippel, W. and Bell, A. E. (2009) Interacting with sexist mentriggers social identity threat among female engineers. *Journal of Personality and Social Psychology*, 96(6), 1089-1103.

Major, B. and O'Brien, L. T. (2005) The Social Psychology of Stigma*. Annual Review of Psychology*, 56(1), 393–421.

Mavor, K. I., Platow, M. J. and Bizumic, B. (2017) *Self and Social Identity in Educational Contexts.* Oxon: Routledge.

McPherson, E., Banchefsky, S. and Park, B. (2018) Using social psychological theory to understand choice of a pSTEM academic major. *Educational Psychology,* 38(10), 1278-1301.

Nosek, B. A., Banaji, M. R. and Greenwald, A. G. (2002a) Math = male, me = female, therefore math ≠ me. *Journal of Personality and Social Psychology*, 83(1), 44-59.

Nosek, B. A., Banaji, M. R., and Greenwald, A. G. (2002b) Harvesting implicit group attitudes and beliefs from a demonstration web site. *Group Dynamics: Theory, Research, and Practice*, 6(1), 101-15.

O'Brien, L. T., Hitti, A., Shaffer, E., Van Camp, A. R., Henry, D. and Gilbert, P. N. (2017) Improving Girls' Sense of Fit in Science: Increasing the Impact of Role Models. *Social Psychological and Personality Science*, 8(3), 301–309.

Ó Siochrú, C. (2018). Boys do maths, girls do English: tracing origins of gender identity and its impact in education. In: Ó Siochrú, C. ed. *Psychology and the Study of Education: Critical Perspectives on Developing Theories.* Oxon: Routledge, 104-122.

Perry, D. G. and Bussey, K. (1979) The social learning theory of sex differences: Imitation is alive and well. *Journal of Personality and Social Psychology*, 37(10), 1699-1712.

Rainy, K., Dancy, M., Mickelson, R., Stearns, E. and Moller, S. (2018) Race and gender differences in how sense of belonging influences decisions to major in STEM. *International Journal of STEM Education*, 5(10), 1-14.

Riegle-Crumb, C., and Morton, K. (2017) Gendered expectations: Examining how peers shape female students' intent to pursue STEM fields. *Frontiers in Psychology*, 8(329), 1-11.

RS Components (2019) Teacher Gender Split DATA. [online] RS Components. Available from: <https://media.rs-online.com/image/upload/infographics/uk/teacher-gender-reveal-in-higher-education/RS_Components__Teacher_Gender_Split_DATA.pdf (Accessed 12/6/2020)

Tajfel, H. (1982) Social Psychology of Intergroup Relations. *Annual Review of Psychology*, 331(1), 1-39.

Van Aalderen-Smeets, S.I. and Walma Van der Molen, J.H. (2018) Modeling the relation between students' implicit beliefs about their abilities and their educational STEM choices. *International Journal of Technology and Design Education*, 28, 1–27.

Van Den Hurk, A., Meelissen, M. and Van Langen, A. (2019) Interventions in education to prevent STEM pipeline leakage. *International Journal of Science Education*, 41(2), 150-164.

Watermeyer, R. (2012) Confirming the legitimacy of female participation in science, technology, engineering and mathematics (STEM): evaluation of a UK STEM initiative for girls. *British Journal of Sociology of Education*, 33 (5), 679-700.

WISE (2018a) *2018 Workforce statistics* [online]. WISE Campaign. Available from: <https://www.wisecampaign.org.uk/statistics/2018-workforce-statistics/>(Accessed 24/7/2020)

WISE (2018b) *Analysis of GCSE STEM Entries and Results* [online]. WISE Campaign. Available from: <https://www.wisecampaign.org.uk/statistics/analysis-of-gcse-stem-entries-and-results-2/> (Accessed 15/7/2020)

WISE (2018c) *Core STEM Graduates 2018* [online]. WISE Campaign. Available from: <https://www.wisecampaign.org.uk/statistics/core-stem-graduates-2017/> (Accessed 1/9/2020)