Systematic review of effectiveness of interventions to increase recruitment of women to STEM careers

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Talent shortfalls are amongst the top concerns of many multinational corporations (Gallardo-Gallardo, Dries, & González-Cruz, 2013; Mäkelä, Björkman, & Ehrnrooth, 2010). However, shortages in the science, technology engineering and maths (STEM) fields are particularly acute, with the House of Commons Science and Technology Committee (HCSTC, 2016) describing a "digital skills crisis", and EngineeringUK (2018) predicting shortages to be exacerbated by rapid growth of new industries. Women are underrepresented in STEM careers globally (Blickenstaff, 2005), giving rise to increased diversity in the workforce as a proposed solution to shortages (e.g. EngineeringUK, 2018; HCSTC, 2016). Over recent years some STEM fields have achieved increased female numbers (WISE Campaign, 2018). However, the proportion of women in information technology (IT) has remained static at 17% for a decade, despite interventions (BCS, 2017).

A metaphor in common use is the "leaky pipeline", with women and minorities dropping out at all stages through education, career choice and career progression (Blickenstaff, 2005). They face barriers (Ibarra, Ely & Kolb, 2013), often arising from gendered role expectations, with descriptive and prescriptive stereotypes leading to gender bias, particularly in male-dominated careers (Eagly & Carli, 2007; Eagly & Sczesney, 2009; Heilman, 2012). STEM organisations fail to offer attractive opportunities to women (Wynn & Correll, 2018), preferentially select male resumes (Moss-Racusin, Dovidio, Brescoll, Graham, & Handelsman, 2012), and lose women in greater rates than men (Anderson, Vinnicombem & Singh, 2010). Bias may arise in performance evaluations, hiring and promotion decisions (Ericsson, 2006; Foschi, 1996; Uhlmann & Cohen, 2007), with differing

standards expected for men and women, to women's disadvantage (Castilla, 2008; Lyness & Heilman, 2006).

Global Talent Management (GTM) literature proposes methods to reduce bias, including process design to avoid individual subjectivity (McDonnell & Collings, 2011), skills training of assessors, and use of multiple assessors and measurements (Dries, 2013; Silzer & Church, 2010). These offset affinity bias (Mäkelä, Björkman, & Ehrnrooth, 2010), and further interventions can reduce network bias arising from women having less access to formal and informal networks than men (Timberlake, 2005). Stamarski and Son Hing (2015) emphasize clear role expectations reduce bias. These interventions ripple throughout the GTM pipeline to attract, select, recruit, progress and retain talent.

Much research has focussed upon the STEM career context, highlighting the importance of a sightline to top female role models to encourage long-term career development of upcoming women (Walsh, Fleming & Enz, 2016). Research has examined gender differences in retention in STEM careers in both academic and organisational settings (Easterly & Ricard, 2011; Stephan & Levin, 2005). However, amongst the many proposals and explanations, Blickenstaff (2005) warns some are without merit. Particularly, interventions that single out individuals for special treatment challenge established GTM processes (Harris & Foster, 2010). Furthermore, context must guide the choice of intervention (Stephan & Levin, 2005). This complicated picture does little to signpost the most effective interventions for practitioners.

Some research has specifically focused upon women's talent development within STEM careers (Mullett, Rinn & Ketter, 2017). However, despite growing practitioner publications of best practices of recruitment for diversity (e.g. PWC, 2017), little recent scholarly research has been identified. While Tsui (2007) reviewed strategies to increase

diversity in STEM fields, she found little quality empirical research or systematic attempt to compare effectiveness. In the intervening decade, discourse and research has progressed. This systematic review fills a gap to examine recruitment interventions for increasing proportions of women in STEM careers. Particularly, it seeks empirical evidence to back practitioner findings, evaluate contextual differences, and provide a means to rank interventions by effectiveness to enable focused effort and resources to those with greatest impact.

Methods

Aims and objectives

This systematic review aims to evaluate evidence of the effectiveness of interventions designed to increase the attraction, selection and recruitment of women into STEM careers.

The research question was guided by a group discussion about diverse recruitment at an industry recruitment conference (TREC, 2019), facilitated by the author. This was followed by an individual interview with the Head of Talent Acquisition in a global software organisation. Many interventions were reported, which included interview panels, blinding CVs to identifying characteristics, changed wording on advertisements, bias training, and the importance of an inclusive culture. This review seeks empirical evidence regarding the effectiveness of these, and other, interventions for diverse recruitment in STEM.

Search strategy, data sources and search terms

A comprehensive search for academic research was carried using the following databases: SCOPUS, Web of Science, PsycINFO, ERIC, Business Source Complete, Academic Search Complete.

The search query was designed to identify studies including recruitment AND gender AND STEM AND intervention terms. The full query is shown in Table 1. The query was

developed iteratively to incorporate relevant studies found from citations in initial results. Due to large numbers of irrelevant results, the search parameters of recruitment, gender and STEM were restricted to the title field. The search parameter of intervention was by keywords and abstract, included to reduce results that were theoretical only.

Table 1 *Search query*

Logical query	Search terms
Recruitment terms*	(Recruit* OR Attract* OR Talent OR career)
AND	AND
Gender terms*	(Women OR female OR gender)
AND	AND
STEM terms*	(STEM OR science OR technology OR engineering OR maths)
AND	AND
Intervention terms**	(Intervention OR increas* OR expand* OR broaden* OR influenc*)

* Search by title

** Search by keywords and abstract

Selection criteria

All types of empirical research were selected, including qualitative, quantitative, meta-analysis and reviews. Results that were theoretical were excluded. Studies that were not reported in English were excluded.

All types of intervention with the aim to with aim to increase number of girls/women selecting STEM subjects and careers were included, regardless of the age of the participants. Papers not relevant to this topic were excluded. Papers more than 20 years old were also excluded, due to rapid evolution of Global Talent Management literature during this time period (Scullion & Collings, 2011)

Due to initial results containing large numbers of conference papers from a single source, conference papers were excluded from selection due to potential introduction of bias.

Table 2 *Inclusion screening criteria*

Criterion	Include	Exclude
Publication year	1999 and later	Before 1999
Publication type	Books, peer reviewed journals, articles, dissertations	Conference proceedings, lecture notes
Language	English	All other languages
Research design	Empirical research, including qualitative, quantitative and mix-methods, meta analyses and systematic reviews	Nonempirical work
Relevance	Any recruitment intervention to increase numbers of women in STEM careers	All other purposes
Full text	Full text available	Full text unavailable

Qualitative data synthesis

Data were extracted systematically from results and captured using a Microsoft Excel spreadsheet. The data extraction protocol is shown in Table 3.

It was not possible to conduct a quantitative meta-analysis due to a paucity of quantitative results. Instead, a qualitative approach was adopted. Interventions were coded from their full text to enable thematic analysis across the body of research (Ryan & Bernard, 2003). Themes were guided by conceptual breakdown and terminology from the GTM literature (Gallardo-Gallardo et al., 2013).

Table 3 *Data extraction protocol*

Extract	**Description**
Purpose	The purpose of the research
Geographic context	The geographic location of the research
Employment context	The employment context of the recruitment: High school, Undergraduate, Academic Faculty, Industry, Government
Intervention type	Description of the intervention
Research design	Qualitative, quantitative, mixed-methods or review
Participants	Demographic characteristics of the participants including age, gender, and where applicable, race
Framework(s)	Any theoretical frameworks that ground the research
Outcomes	Summarised research outcomes and conclusions

Results

Included studies

A total of 178 search results were found. Eleven studies remained following down selection. Two were reviews (not systematic), six were quantitative and three qualitative. Table 4 breaks down the search results by database, and Figure 1 illustrates the selection flow.

Table 4 *Search results by database*

Database	**Number of items**
Scopus	85
Web of Science	42
PsycINFO	28
Business Source complete	3
ERIC	15
Academic Source complete	5
Total	**178**

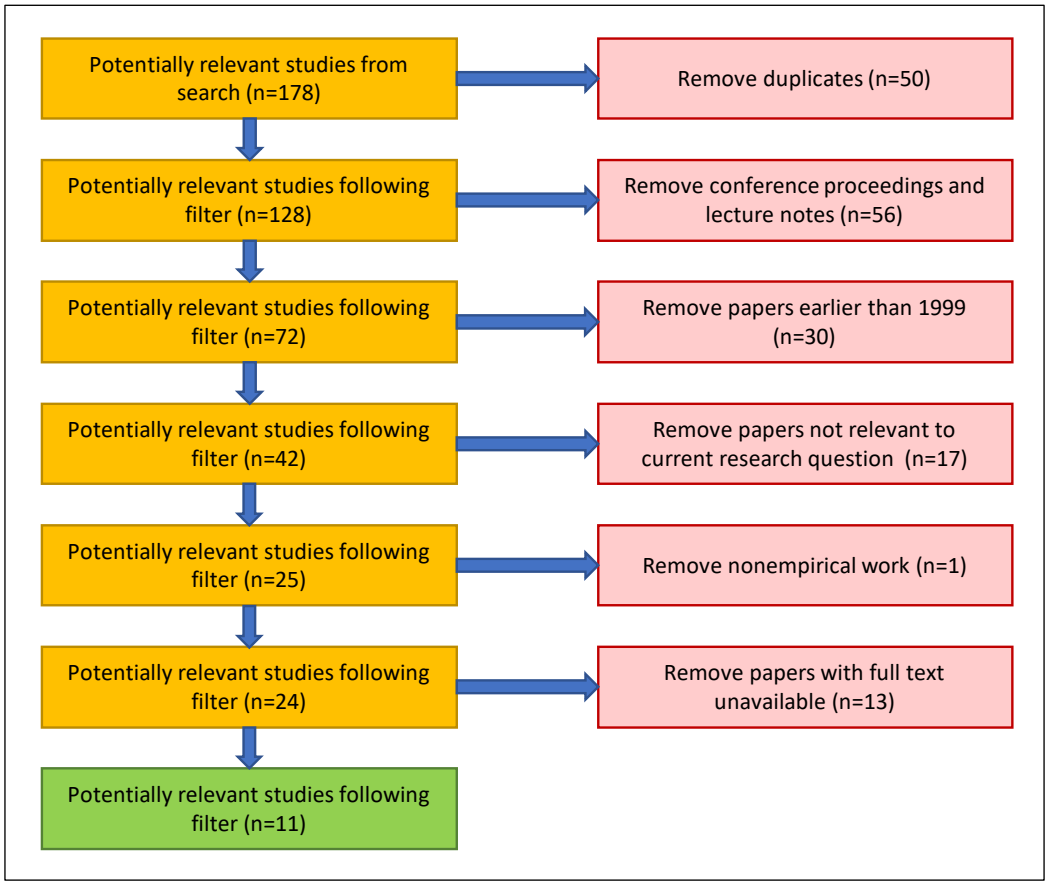

Figure 1 *Selection flow diagram*

Excluded studies

117 studies were excluded. 56 were conference proceedings, and 29 of these were publications from a single conference. As described in Methods, these were excluded to reduce possibility of bias arising from a single source.

Summary of study findings

Table 5 presents a breakdown of each study. Results spanned research disciplines, but were skewed towards educational, not organisational, settings. Findings are organised here by themes of attraction, selection, and broader, strategic interventions.

Attraction.

Hands-on activities. All were targeted at students. Carbonaro, Szafron, Cutumisu, and Schaeffer (2010) found computer game construction to be equally appealing to both genders for attraction to computer science (CS). Ivey, Golias, Palazolo, Edwards, & Thomas (2012) measured outcomes from a one-week engineering programme, finding increase to girls' confidence and awareness. Lourens (2014) reported an engineering project for female undergraduates, highlighting their positive reaction to teamwork and range of skills used. Schorr (2019) found girls were introduced to CS one year later than boys. She found a robotics activity to be less enjoyable for girls than information-sharing, possibly due to the individual orientation of the task.

Information-based training. Jackson and Charleston (2012) found targeted presentations for African Americans to benefit women more than men, concluding programmes should be tailored to race and gender.

Role models, mentors and visible women. Drury, Siy and Cheryan (2010) concluded female role models are more important for retention than recruitment, however women's STEM identity is important. Alvarado and Judson (2014) measured impact of attending the

Grace Hopper Conference for female undergraduates, finding this to increase intentions and rates of further CS study. Others used female mentors as a part of interventions (Carrigan, O'Leary, Riskin, Yen, & O'Donnell, 2017; Ivey et al, 2012; Lourens, 2019)

Targeted Advertising. Glass and Minnotte (2010) found increased female applicants to academic STEM roles resulting from targeted advertising.

Selection.

Bias training. - Hutchings & Kovach (2019) reported use of bias training but made no evaluation of its effectiveness.

Women in the hiring process. Glass & Minnotte (2010) found, unexpectedly, that the percentage of women in the hiring department had no relationship to numbers of female applicants, and a negative relationship between women in the search panel and female applicants.

Strategic Interventions.

Several studies researched broader, strategic programmes that gave rise to interventions across many categories. Noteworthy are Hutchings & Kovach (2019), who emphasize appeal to shared values, and Frieze and Quesenberry (2019) who report cultural, not curricular, changes to have led to 49% female students of the Carnegie Mellon University (CMU) CS programme.

Comparison of studies

The range of theoretical frameworks and operationalisation of outcomes prevents comparison and ability to rank interventions by effectiveness. Although some studies identified several interventions (Glass & Minotte, 2010; Hutchings & Kovach, 2019; Lourens, 2019), none rated comparative effectiveness, and some made no evaluations at all.

Contradictory conclusions arose from Jackson and Charleston (2012) and Frieze and Quesenberry (2019) regarding demographic specific interventions vs. a holistic approach.

Quality of studies

The overall quality of research was poor. Seven studies stated the theoretical framework guiding research, four did not. Most quantitative studies were quasi-experiments due to self-selection of participants into groups, but this was poorly explained. Neither review was systematic.

There was a general lack of statistical methods reported, with most lacking significance tests and information about reliability and validity. Inclusion of control groups was rare. Some papers omit key information such as number of participants. Schorr (2019) was alone in using experimental conditions with random selection, statistical testing and regression analysis.

Table 5 *Characteristics of included studies*

Author(s)	Publication Type	Purpose	Geographic context	Employment context	Intervention type	Research Design	Participants	Frameworks	Outcomes
Alvarado & Judson (2014)	IT Journal	To investigate the impact of targeted conference attendance for female undergraduates	United States	University - undergraduates	Conference attendance	Quantitative	First year female undergraduates between 2006-2011		Positive results. Increased favourable attitude to CS, intentions to continue or major in CS studies, and increased rate of continuation of CS studies
Carbonaro, Szafron, Cutumisu, & Schaeffer (2010)	IT Journal	Investigate use of computer game construction to attract women to computer science	Canada	High school	Computer game construction during grade 10 English classes.	Quantitative	50 grade 10 female (24) and male (26) students. Multi-ethnic.	Constructivist learning theory	Positive results, with good majority of students gaining skills and enjoying the activity. No difference in enjoyment level between genders.
Carrigan, O'Leary, Riskin, Yen, & O'Donnell (2017)	IT Journal	Investigate selection of women with PhDs but non-academic careers for increasing the numbers of female academic faculty	United States	University - faculty	"On-ramping" of female PhDs with non-academic STEM careers selected for academic faculty roles	Qualitative	10 female PhDs with non-academic science and engineering careers in industry and government	Mid-career re-entry, non-linear careers.	Identified four critical phases in transition from non-academic to academic careers. A challenge unique to women is coping with gender discrimination.
Drury, Siy, & Cheryan (2010)	Psychology Journal	Review interventions to conceptually differentiate effects of female role models for recruitment and retention of women in STEM	Not stated	University - students and faculty	Use of role models	Review of interventions (not systematic)	Review of interventions. Those included all researched university students and faculty	Identity, stereotypes	Conclude that female role models are more important for retention that recruitment, and men can be effective role models for recruiting women into STEM fields.
Frieze, & Quesenberry (2019)	IT Journal	To identify effective interventions that increase attraction of women to computer science programmes	United States	University - undergraduates	Summary of several interventions	Review of interventions (not systematic)	Undergraduate students		Conclude that institutional support, culture and environment change, rather than curriculum change, brings greater proportions of women to their computer science course. Feeling of belonging and academic fit is important

Table 5 (continued)

Author(s)	Publication Type	Purpose	Geographic context	Employment context	Intervention type	Research Design	Participants	Frameworks	Outcomes
Glass, & Minnotte (2010)	Education Journal	To identify strategies that increase women's representation in academic STEM jobs	Unites States	University - faculty	Various recruitment interventions. Data captured for applicant pool over 6 years	Quantitative	Applicants (N=3253) for all tenure track searches over a 6-year period at a large western university	Cognitive bias, gender-differentiated social networks, gender inequality	The more female applicants, the greater the likelihood that a woman is shortlisted and hired. Placing adverts in a venue targeting women increases the numbers of female applications Unexpected finding that one or more women in the search committee decreased the percentage of female applicants.
Hutchins & Kovach (2019)	HR Journal	To identify key interventions that increase STEM women faculty numbers and advancement, and how this aligns with HRD expertise	United States	University - faculty	National Science Foundation's ADVANCE programme.	Qualitative	Five institutions who receive an ADVANCE grant, between 2010 and 2015.	Gendered notions of work (Morimoto et al., 2013)	Many interventions to reduce recruitment bias were recorded: Cultural interventions addressing shared values, clustered faculty hiring, multiyear hiring plans aligned with research strategies, interdisciplinary search committees, training, dual-career hiring programmes, microaggression and bias training
Ivey, Golias, Palazolo, Edwards, & Thomas (2012)	Engineering Journal	To present assessment findings from the first 2 years of a programme to attract students to transportation engineering careers	United States	High school students	A weeklong program to introduce students to transportation engineering.	Quantitative	26 girls and 30 boys in 2010 24 girls and 20 boys in 2011		Positive results. Increased confidence and awareness. Gender differences in belief that men and women are equally suited to engineering careers. Family support is important in choice of college major.

Table 5 (Continued)

Author(s)	Publication Type	Purpose	Geographic context	Employment context	Intervention type	Research Design	Participants	Frameworks	Outcomes
Jackson & Charleston (2012)	Education Journal	To examine the differential gender outcomes of a computer science outreach programme aimed at broadening participation of African Americans	United States	University - undergraduates	Targeted presentations as part of the African American Researchers in Computer Science programme.	Quantitative	76 African American students at predominantly white institutions. 55.5% male, 45.5% female		Benefit seen by both genders, but women more than men. Positive changes to attitude and interest. Racial differences also important and conclude programme should be tailored by both race and gender.
Lourens (2014)	Engineering Journal	Research co-curricular interventions to improve women in engineering student's self-efficacy	South Africa	University - undergraduates	Women's engineering leadership development programme	Qualitative	Undergraduate	Self-efficacy	Interventions positively influenced participants self-efficacy. Conclude the co-curricular interventions could be incorporated into a formal engineering curriculum.
Schorr (2019)	Psychology Journal	To evaluate interventions for impact to interest in professional careers in information science	Germany	High school students	Vocational counselling interventions	Quantitative	134 high school students, aged 14-18	Gender stereotypes, stereotype threat, domain masculinity	Information condition more effective than activity condition. Father's role affects gendered perceptions of ICT differently for boys and girls. Self-doubt risks girls leaving the field before entering.

Discussion

Several studies were identified of interventions to increase female recruitment to STEM careers. However, not all are evaluative, and there is skew towards educational rather than organisational settings. Findings are predominantly Western in origin, so may not generalize to other cultures (Dries, Cotton, Bagdadli, & de Oliveira, 2014). Many, but not all, interventions posed as best-practice in practitioner literature were covered by the identified studies, with notable omissions of "blind" resume screening and job advertisement wording (PWC, 2017). Comparison of intervention effectiveness was not possible due to range of theoretical frameworks, operationalisation of outcomes, and research quality issues.

Industry and academia have differing needs, expectations and cultures (Carrigan et al., 2017), and more industry specific empirical evidence is needed to draw conclusions regarding recruitment into industry. The paucity of research in organisational settings reflects findings by McDonnell and Collings (2017) that GTM scholars focus on broad organisational concerns, rather than specific practices like recruitment, leading to a significant knowledge gap in how talented individuals are recruited.

Schorr's (2019) findings that girls are introduced to CS later than boys echoes Ericsson's (2006) deliberate practice requirement for high performance, and links to reduced development and fewer opportunities available for girls. One intervention at CMU removed requirement for previous programming experience to address this (Frieze & Quesenberry, 2019), but this approach increases necessity for recruiters to recognise potential in place of performance (Silzer & Church, 2010), which itself may be subject to bias (Eagly & Sczesney, 2009).

Teamwork was identified as of particular interest to girls (Lourens, 2014; Schorr, 2019) and impacted effectiveness of interventions. Teamwork orientation is a benefit to

many engineering and technology practices (Poppendieck & Poppendieck, 2006), highlighting a benefit increased gender diversity may bring with reduced emphasis on individual performance (Pfeffer, 2001).

Several studies touched upon STEM identity, values alignment and sense of belonging to attract women into STEM careers (Drury, Siy, & Cheryan, 2010; Frieze & Quesenberry, 2019; Hutchins & Kovak, 2019), the same set that took the most strategic approach to interventions. These most closely match the GTM literature regarding alignment to organisational strategy, culture and values for identification and management of talent (Stahl et al., 2014; Mullet et al., 2017). The resulting 49% women at CMU studying CS (Frieze & Quesenberry, 2019) suggests success in this approach.

Limitations and further research

Despite growing practitioner interest in hiring for diversity (PWC, 2017), few good quality academic studies were identified. It is possible that the search strategy was too restrictive, particularly due to the interdisciplinary nature of the subject and differing terminology across disciplines. Greater use of keywords and manual effort to identify relevant papers may elucidate additional relevant research.

There is also possibility that publication bias skews results. Given the large numbers of conference papers excluded, many academics are writing about this topic but not gaining peer-reviewed publication. Further research should incorporate these unpublished papers.

Conclusion

Practice appears to be outpacing research in recruitment methods to increase proportions of women in STEM careers. There are many proposed routes to eliminate the gender disparity, but with little empirical testing in organisational settings. Diversity of interventions and poor quality of studies hinders comparison of effectiveness of interventions.

However, most findings show positive outcomes. Further empirical research is needed to enable comparison to permit practitioners with limited resources to prioritise the most effective methods.

[*Word count (excluding tables): 2,198*]

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