Chemistry Education Research and Practice

Accepted Manuscript

This article can be cited before page numbers have been issued, to do this please use: J. Miller-Friedmann, A. Childs and J. Hillier, *Chem. Educ. Res. Pract.*, 2017, DOI: 10.1039/C6RP00252H.

View Article Online
DOI: 10.1039/C6RP00252H

Approaching Gender Equity in Academic Chemistry: Lessons learned from successful female chemists in the UK

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Abstract

The internationally acknowledged gender gap in science continues to be an unrelenting concern to science educators; aggregate data in the UK show that both recruitment and retention of women in academic science remain relatively low. Most published research focuses on women in the broad field of science, generates correlations or predictions, or examines the reasons why women do not participate in fields like physics or engineering. Previous work has not yet addressed how women have found ways to succeed in particular fields, such as chemistry, or how successful pathways may be applied to recruitment and retention efforts in those fields. This study investigated the experiences of successful British female chemists, in order to uncover coping mechanisms and commonalities that may illuminate obstacles and solutions particular to women in chemistry. Four case study semi-structured life history interviews with highly successful British female chemists revealed common experiences that helped the women in the study to succeed. Of these, two resonated with the literature: having an integrated support network, and the ability to cope with financial and career instability; choice of subfield and adaptation of (unconscious) bias are offered as new insights. The findings suggest changes in policy and practice that would provide particular kinds of support for women in chemistry at school and university level. Implementing these changes may be the impetus needed to approach gender parity in UK academic chemistry from undergraduate to Professor.

Introduction

According to the House of Commons Science and Technology Committee report of 2014, recruitment and retention of women in Science, Technology, Engineering, and Mathematics (STEM) careers is crucial to establishing a socially mobile and fair economy, and creating opportunities for innovation and discovery that are currently inaccessible (Miller et al., 2014). This report then enumerated a number of explanations for the continued gender gap in science, citing research literature, including bias and discrimination as well as science as a career being incompatible with lifestyle choices (Miller et al., 2014). However, this report, and many others like it across the globe, did not consider that there are differences in the fields of science and the experiences of women in particular fields in science may vary. Most research that looks at the gender gap either does so for science as a general discipline (e.g., Ceci & Williams, 2011b; Commission, 2012), as correlative or predictive studies (e.g., Dabney et al., 2012; Morgan, Gelbgiser, & Weeden, 2013) or investigates why women do *not* choose to participate in fields like physics or engineering (e.g., Lock, Hazari, & Potvin, 2013). There is relatively little research on why women choose to participate in academic chemistry. In one sense, the study reported here was exploratory: working under the assumption that the issues that hinder women are not necessarily the flip side to the same issues that help them, this study probed life histories to find unique mechanisms or pathways for achieving success. Whilst recognising that each field of science is unique in its history and tradition, this study focussed on one broad field, chemistry, in order to understand the environment in that field and the pathways that can be followed that may help women to advance. By looking at what has worked in the past, it may be possible to devise effective methods for realising the House of Commons' goal in future: gender equity.

Background and Literature Review

For many years, researchers, academics, scientists, government, and international councils insisted that science was male-dominated because men were genetically inclined towards a greater talent for science and maths than women (Casey,

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1996; Geary, 1995; Halpern, 1997; Halpern & LaMay, 2000; Spencer, Steele, & Quinn, 1999). Whilst this theory seemed to lose traction in the 1980s and 1990s, there are those who continue to investigate whether intrinsic sex differences may accumulate over time to become gender-based academic advantages. For example, Ceci, et al, recently published a paper articulating the arguments based on sex difference, including arguments that spatial and mathematical aptitudes of women were lower than men, indicating a lower probability that (those) women would excel in maths. They conclude that the evidence in the literature is contradictory and unconvincing as an independent explanation for the gender gap in science (Ceci, Ginther, Kahn, & Williams, 2014). Other, more general theories include social cognitive career theory (Lent, Brown, & Hackett, 1994), which suggests that social and school environments are as influential on career intentions as interest, self-efficacy, which suggests career choice is based on one's perception of best chances of success (Bandura & Locke, 2003; DiBenedetto & Bembenutty, 2013), and 'science identity,' which implies that the creation and acceptance of self as scientist is essential to attempting a career in science (Calabrese Barton et al., 2012; Johnson, Brown, Carlone, & Cuevas, 2011). An analogous theory of perceived brilliance posits that both students and educators assume that only those students who have an innate talent for particular science fields will succeed (Leslie, Cimpian, Meyer, & Freeland, 2015). Many of these studies focus on the gender gap in science as a whole, but not necessarily on the experiences of genders within particular fields.

These findings, however, are about science as a general subject, and not necessarily specific to particular fields within science. The current gender landscape for biosciences, for example, differs from that of chemistry or physics (Smith, 2011). And whilst there is considerable research on the socio-cultural obstacles to women entering and staying in science, or speculation about factors that may influence retention, there is far less research focused on factors that have been, in practice, shown to have impact specifically on women in chemistry. This exploratory study addresses both of these points by probing how women in chemistry have become successful in their fields.

Women in Chemistry

In the broadest sense, chemistry, as a particular discipline within science, has had recent achievements with regard to gender equity: firstly, recruitment of women into the beginning stages towards a career in chemistry is increasing (Bøe, Henriksen, Lyons, & Schreiner, 2011; Ceci & Williams, 2011; Dabney & Tai, 2014; Hunter, Laursen, & Seymour, 2007; Laursen & Weston, 2014a; Smith, 2011). Secondly, undergraduate women in chemistry have evolved from a clear minority in the early 1970s to representing nearly half of all undergraduate chemistry students in recent years. The early 1970s was the first time data from the UK were collected and collated by a single source (Universities' Statistical Record (USR)) so that demographic and academic data could be compared across institutions and throughout the nation. Whilst these numbers are encouraging, and do show improvement in recruitment (the number of women who begin studying chemistry), there are two other sets of numbers that should be considered. First, it is the proportion of women in chemistry that is improving, not the numbers of students participating. That is, the number of women entering into chemistry courses at University has remained around 7000 for almost 20 years (Higher Education Statistics Agency, 2016). This would indicate that proportionately fewer men are choosing to participate in chemistry, thus increasing the overall proportion of women in undergraduate chemistry. Second, although women comprise over 42% of chemistry students at the undergraduate level, and 29 % of junior faculty, approximately 9% of chemistry professors are female ("HESA - Higher Education Statistics Agency - HESA - Higher Education Statistics Agency," 2016).[1]

[1] Across academic science, the number of female professors is low: according to data released by

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These numbers imply that retention is still very low for women in chemistry; the literature has tried to address the causes for this lack of retention.

In trying to research why retention of women in chemistry is low the question arises as to whether many of theories proposed could be applied across the sciences? The difference between women in chemistry and women in general science is that, as the discipline approaches gender equity, at the undergraduate level, there is an expectation that female attrition and other problems associated with female retention would cease to exist. This expectation is based on a theory of 'critical mass,' or the minimum proportion of women needed in a department in order to significantly change the gendered dynamics of the department (Chapman et al., 2011; European Commission, 2012; Laursen & Weston, 2014b; Lewis & Richmond, 2010; Wilson et al., 2014). Etzkowitz, et. al., define this proportion as 15%; undergraduate and junior faculty chemists in the UK far exceed this proportion and, by the critical mass argument, department dynamics should be fundamentally changed in women's favour, but the statistics show that women continue to leave academic chemistry in greater proportions than men (Newsome-Lober, 2008). This should prompt one to ask what is different about chemistry, why are women still leaving the field and why critical mass theories do not seem to apply in this case. The next section goes on to consider these questions.

The Realities of Critical Mass

The basic concept of critical mass implies that there is 'safety in numbers,' that the gendered minority, in general, should feel more comfortable amongst a large minority rather than as a unique individual. There are those who argue that establishing a critical mass of women, beginning at the undergraduate level, is crucial to decreasing attrition and reaching a gender equity (Chapman et al., 2011; Smith, 2011). The implication is that with an increase in the proportion of women undergraduates in a department, there will be an increase both in recruitment of women to the department and an increase in the proportion of women who persist in their careers to Professor. Clearly, this is not the case in chemistry.

Etzkowitz, et.al., argue that, once a department reaches critical mass, the minority population then subdivides by age and seniority into two distinct groups: the more senior women, who subconsciously act to maintain the status quo within the department, and the junior women, who actively try to ameliorate the status of young female chemists within their department (Etzkowitz et al., 1994). Etzkowitz et al., speculate that the more senior women have presumably risen to their positions during a time when the department had fewer women, or when they were likely one of very few or even the only woman in the department. Their career trajectory is based on achieving success whilst negotiating clear gendered obstacles; as a result, they may now feel as though it is in their best interests to maintain the status quo of the environment in which they have managed to prosper. In maintaining the status quo, they are likely to be propagating gender stereotypes, questioning the intellectual and practical skills of junior female chemists, and, overall, acting according to the unconscious biases that both hindered their early careers and helped them to become members of the elite (Etzkowitz et al., 1994; European Commission, 2012; Newsome-Lober, 2008). It could be perceived that actively helping younger/junior women, even via mentoring students in a stereotypically 'feminine' (and expected) fashion (Kuck & Marzabadi, 2007), is, at best, either not to their benefit, or, at worst, detrimental to maintaining their authority and prominence in the department. For the junior female faculty, however, other research has shown that they have entered the next stage of their professional career with the assumption that it would be as female-friendly as the previous stage, whilst they were students.

HESA, as of the 2007/08 academic year, 6% of UK physics Professors, 9% of chemistry Professors and 15% of Biosciences Professors were female. These numbers indicate that there are indeed differences between the fields and it may be beneficial to look at each separately.

With the (limited) power of their sub-faction behind them, they tend to be more conscious of gender bias and active in their demands for equality (Birgeneau, 1999; Chapman et al., 2011; Etzkowitz et al., 1994; Greene, Stockard, Lewis, & Richmond, 2010; Grunert & Bodner, 2011b; Kuck & Marzabadi, 2007). These women tend to be open to mentoring female students, but are not prominent enough in the department/subfield to be a popular choice for students and/or project their new-found understanding of gendered politics (both departmental and in their wider international subfield) onto their students by insisting on student independence and 'toughness,' male-associated traits (Kuck & Marzabadi, 2007). For both groups, gender bias remains a factor in their treatment, both by men and by other women; from overt sexism to a more subtle unconscious bias, female chemists are still subject to discrimination. Although chemistry, as an academic discipline, may have a critical mass of women in its intake at the undergraduate level, and at the junior faculty level, forces, such as unconscious bias and overt discrimination, still seem to be operating to maintain male dominance.

Subtle and Overt Discrimination

As argued above despite having reached critical mass in many cases, researchers have shown that unconscious bias continues to function in chemistry departments, by both men and women (Easterly & Ricard, 2011; European Commission, 2012; Hobbs, Holland-minkley, & Millett, 1999; Laursen & Weston, 2014; Nosek & Smyth, 2011). Unconscious bias can be subtle: it can manifest as interrupting a woman during a meeting, but listening intently to her male colleague; checking one's watch or emails during a meeting being led by a woman; outwardly questioning a woman's science, in a way that one might not do to a man; or conducting a key conversation about research in the lab without the woman who is integral to the work (Basford, Offermann, & Behrend, 2013).

Unconscious bias can also lead to more aggressive, overt discrimination, which may either be verbal or physical. Verbal discrimination may take the form of comments about one's appearance, gender jokes, or openly questioning one's abilities or commitment to work because one is female (Clancy, Nelson, Rutherford, & Hinde, 2014; European Commission, 2012; Pomeroy, 2015). Physical assault can also take a variety of forms, from unwanted contact, such as a hand on the shoulder, to non consensual sexual contact (Clancy et al., 2014; De Welde, Laursen, & Gulf, 2011; Jahren, 2016). Both subtle and overt forms of bias work to undermine women's feelings of belonging and exacerbate feelings of isolation, making it difficult to perform well and to stay at a job and in a place where she is made to feel inadequate and unwelcome (Ceci & Williams, 2011; De Welde et al., 2011; Robnett, 2015). Women's own biases also work to consistently question self-efficacy and reinforce feelings of inadequacy as well as conflicts in how she defines herself, or her 'identity.'

Identity Conflicts

As unconscious bias guides the thoughts, decisions, feelings, and actions of most people, so too does it help to establish, confirm, and continually redefine the notion of identity (MacDonald, 2014). As the literature suggests, science identity, or the association of oneself with 'scientist,' and the acceptance of this sense of self has been shown to be challenging to reconcile with other possible identities (Ahlqvist, London, & Rosenthal, 2013; Archer et al., 2010; Calabrese Barton et al., 2012; Fraser, Shane-Simpson, & Asbell-Clarke, 2014; Irving & Sayre, 2013; Jackson & Seiler, 2013; Johnson et al., 2011; Krogh & Andersen, 2012; Lock et al., 2012; Olitsky, 2007). For example, the literature shows that a science identity may be at odds with one's identity as a woman, and many women feel that they must negotiate with their definitions of self in order to accommodate being both 'scientist' and 'woman' (Archer et al., 2012; Danielsson, 2012). This links to the arguments made above about unconscious bias and that

DOI: 10.1039/C6RP00252H

one's preconceived notions of 'scientist' and 'woman,' for example, are based on the same ideological sources that produce unconscious bias, and strongly associate 'scientist' with 'man.' It may therefore become difficult for some women to think of themselves as feminine and simultaneously think of themselves as scientists, two identities which, on the spectrum of gender, seem to be diametrically opposed (Carli, Alawa, Lee, Zhao, & Kim, 2016; European Commission, 2012; Hazari, Tai, & Sadler, 2007). The identity negotiations which ensue once a women chooses to participate in science include redefining 'woman,' 'scientist,' and 'man,' and which personality traits, habits, and assumptions associated with each may be discarded or re-imagined in order to formulate a unifying sense of self (Carli et al., 2016; European Commission, 2012; Hazari et al., 2007). Identity formation is a more recent theory in science education, and stems from previous work by Albert Bandura called Social Cognitive Theory, which postulates that students learn from their environments and from those with whom they interact in a wide variety of ways (Bandura, 2001). Self-efficacy also arises from Social Cognitive Theory, as one of the central elements to understanding how children learn: "Self-Efficacy is the belief in one's capabilities to organise and execute the sources of actions required to manage prospective situations" (Bandura, 1986). In essence, one's internal estimation of one's success in a given situation will influence how one behaves and whether or not one decides to participate in that situation. Self-efficacy may be an influential factor in choosing whether or not to study science, as stereotype and preconceived gender associations would indicate that women should believe that they are less likely to succeed in science, since science is ideologically associated with men (Carli et al., 2016; European Commission, 2012; Hazari et al., 2007). Only those women who either eschew gender association with science or have a higher self-efficacy in science will take the risk of participating and choose to pursue a career in science (Bandura, Barbaranelli, Caprara, & Pastorelli, 2001; DiBenedetto & Bembenutty, 2013; Diekman, Brown, Johnston, & Clark, 2010; Fouad & Smith, 1996; Hazari, Sonnert, Sadler, & Shanahan, 2010; Lent et al., 1994; Sadler et al., 2012). Female chemists may therefore need to renegotiate, or reconcile, their associations with and adherences to different identities in order to construct a unified identity and set of personal associations. This unified identity construct is vital to any scientist in order to be productive and creative, and to feel confident enough to take risks and to try new things. In addition to feeling confident, research suggests that a steady support network is equally necessary to inspire a young scientist to both stay in the profession and to innovate; whether or not all chemistry students receive the kind of support they need is still in question.

Lack of Support

Research has shown that a lack of support and subsequent feelings of isolation seem to be one of the most influential factors in determining whether one will persist in her intentions in academic chemistry (Ceci & Williams, 2011b; Commission, 2012; De Welde et al., 2011; Etzkowitz et al., 1994). During undergraduate or graduate studies, support that should be found in one's supervisor, academic advisor, or in student support groups has been shown by research to be missing in many chemistry departments (Dabney & Tai, 2014; De Welde et al., 2011; European Commission, 2012). Junior faculty have been found to have very little support—they are either not assigned mentors or feel that their mentors are not supportive in the ways that would be most helpful, and/or feel that their department is not as supportive as they would have hoped (De Welde et al., 2011; European Commission, 2012; Hobbs et al., 1999; Miller et al., 2014). Most of the researchers who have looked at mentoring and support have suggested institutional level reforms that include the formation of student groups and better communication about the kinds of support available to students.

Summary of Literature Review

DOI: 10.1039/C6RP00252H

The literature is expansive with regard to its investigation of the gender gap in science. These more generalised studies frequently investigate why women are either not choosing to participate in science or why they leave science. The multitude of these identify several reasons why the gender gap persists, including, but certainly not limited to: sex differences, social cognitive career theory, self-efficacy issues, problems with establishing a science identity, and tenacious stereotype that posit males as scientists. The vast majority of working papers and reports similarly examine the gender gap in science or STEM, coming to many of the same conclusions. There are some papers that focus on factors that help one to achieve success, but these are similarly aggregated as women in science or underrepresented minorities (gender, race, ethnicity, socioeconomic status, religion, etc.) in chemistry, as opposed to women in chemistry (Korpershoek, Kuyper, van der Werf, & Bosker, 2011; Smith & White, 2014; Wilson et al., 2014). Research that is more specific to chemistry is compelling and robust evidence of the many ways in which women are often discouraged or even excluded from becoming successful chemists. Whilst much of the research on women in chemistry is similar in nature to that on women in science, it does delve deeper into the experiences of women in this particular field, citing both overt and subtle bias, a lack of support, and conflicts in self-efficacy and chemistry identity formation as causes for the gender gap in chemistry. Nevertheless, there are *some* successful women chemists and no research seems to have been conducted into why – what or who enabled these women to continue onto success when so many others left. This study took a different approach and attempted to identify how successful female elites in chemistry have navigated obstacles and barriers and looks at methodologies and coping mechanisms in detail.

The Current Study

In order to investigate the case for women in chemistry in the UK, the research first sought to establish the current situation for women at the earlier stages of a career in academic chemistry. At the undergraduate level, women are nearing a gender parity with men and comprise 43% of chemistry undergraduates. There is a steep attrition between undergraduate and junior faculty level; 29% of chemistry junior faculty are female. If men abandoned the academic chemistry pathway at the same rate as women, one would expect that the proportion male/female would not change from undergraduate to junior faculty. These numbers imply that women are choosing not to participate in academic chemistry at a greater rate than men. With this statistical snapshot, deeper questions surfaced: why has critical mass at the undergraduate and junior faculty levels not effected change throughout the field? It was determined that the best way to probe this complex question would be through semi-structured interviews with those who are among the 29%, or those who have persisted to become professors or leaders in their subfield. The literature seems to emphasize so many ways in which women can be persuaded to leave academic chemistry and reasons why they would not choose to participate at all in the field; what is different for female chemistry associate professors?

Research Question

In an attempt to uncover the ways in which women in chemistry may have experiences unique to their field and how these experiences have shaped their ideology and practice to assist, rather than obstruct, their pathway to success, this study endeavoured to answer the following research question:

> For those British women who have persisted through beginning stages and become academic chemists, in which ways have they experienced

the gender gap and which experiences have helped them succeed?

Methodology

In order to answer the research question the study consisted of multiple qualitative case studies of women who have successfully navigated their pathway to the junior faculty levels of the academic chemistry hierarchy in order to probe their experiences and methods for coping, persisting, and managing. In this way, it was hypothesized that the study may yield insights into how women, specifically female chemists, may remain in academic chemistry.

Qualitative Case Studies

As said above, in an endeavour to identify factors that have helped women to become highly successful in chemistry, this study sought to speak with a sample that could be classified as 'elite,' in that the participants are members of a very small minority who meet the exclusive parameters of this research. Whilst 'elite' in education research is normatively a reference to policy-makers and other politically-aligned individuals (Lancaster, 2016; Nudzor, 2013; Selwyn, 2012; Walford, 2012), this study seeks to redefine 'elite' for the purposes of Science Education as those with "close proximity to power or particular professional expertise (Lancaster, 2016)" who have achieved measurable international success in their field. 'Elite' was therefore defined as those who have either:

1. Applied for or been awarded the title of Professor,
2. Been awarded a competitive grant from an internationally recognised organisation and/or scheme (such as European Research Council (ERC) grants), or
3. Been recognised for her scientific achievements by an organisation or institution outside of her university (such as Royal Society or Women in Science and Engineering (WISE)). There are few women in the UK who meet any of these parameters; the women in this study met at least two. It is therefore reasonable to call the participants both 'elite' and 'successful,' as they are defined as elite by this study and would likely be defined as successful by many in their field.

Although there were a number of ways in which this research may have been conducted, the semi-structured interview method was chosen for three reasons. First, since the secondary statistical analysis implied that, overall, chemistry departments have reached a critical mass for female undergraduate students but continue to have high levels of attrition for female faculty, interviews were deemed appropriate in order to further explore the meanings and explanations behind the numbers (Creswell & Creswell, 2013; Stewart, Gill, Chadwick, & Treasure, 2008). Second, the hope of this study is to uncover previous unidentified factors contributing to women's success in science by providing successful female chemists with an opportunity to speak about their own experiences. One of the benefits of the interview method is to "hear silenced voices" (Creswell & Creswell, 2013), which, for the purposes of this study, would refer to the disempowered amongst the general population—female faculty (disempowered minority group) in chemistry departments (general population). In addition, the form of the interview drew on feminist standpoint theory which argues that a feminist line of inquiry begins from accounts of women's lives, and that these accounts will provide a more accurate understanding of "women's lives, men's lives, and the whole social order"(Harding, 1986; Hughes, 2001; Sinnes, 2006; Smith, 2006). Because the research was an attempt to understand why critical mass at the beginning levels has not altered the gendered disproportion of faculty at junior faculty level, interviews seemed to be a more effective method of investigation. The interviews still needed to be guided by the interviewer, and so the semi-structured method was employed in order to probe for both depth and breadth in the participants' lives and experiences.

Participants

The primary list of possible participants was generated from the Royal Society fellowship directory, and chemists were further researched online for evidence of esteem, grant-funding, and current title/position. The list was narrowed down to five possible candidates, who met at least two of the three parameters, before recruitment commenced. The sample was recruited via two methods, online and a combination of online and network. The first method, targeted online recruitment, consisted of emailing directly potential participants, and providing them with a description of the project, an abstract, and an explanation of why they, in particular, were being asked to participate. The second method, a combination of online and network, consisted of the participant being contacted about the project via a third party with whom both the researcher and the respondent were acquainted, who then introduced the respondent to the researcher via email. The respondent was then sent the recruitment email, and after her consent to participate, subsequent plans to meet were made through email and, closer to the interview date, text messages. Three of the four participants were recruited in the targeted method, one by the combination method. The fifth possible participant declined the invitation to participate.

The sample for this study consists of four British female successful academic chemists. 'Success,' as defined for this study, is both defined in the same way as 'elite,' and means that the participants are currently in tenure-track positions at internationally competitive research-intensive universities, and all have received internationally competitive awards, fellowships, or grants for their scientific work. All participants are white and middle class, two have children, two are married (M) (the other two have long-term partners (LTP)), the participants range in age from 28 to 43, and all are in their early to mid career stage, within 10 years of becoming professor. Two of the participants preferred to conduct their interviews in their offices; the other two preferred to meet in private homes outside of normal working hours. Each participant situates herself in a subfield of chemistry unique to the sample.

Table 1: Respondent Demographics

Respondent	Parameter Met	Marital Status	Location for interview	Children?
Ava	Grant, award	M	Private home	N
Beth	Professor, grant	LTP	Office	N
Charlotte	Grant, award	LTP	Private home	Y
Ella	Professor, grant, award	M	Office	Y

Table 1: Respondent Demographics. Please note all names have been changed to ensure participants' anonymity.

Interviews

Semi-structured life history interview schedules were designed to be simultaneously confirmatory and exploratory. Therefore, questions were planned that touched on issues in the literature, e.g. issues of self-efficacy, confidence, and support, and the researcher constructed other questions that hypothesized reasons for success, e.g., attitude and positive mentoring. In addition, items were added to the schedule that designed to bolster rapport, such as discussions about siblings or the participants' children. Participants were asked for two-hour time blocks for the interview, with the possibility of more time for follow-up questions.

There were two major components to the interview preparation. The first was a substantial online investigation of social media, including Facebook, LinkedIn, Twitter, Instagram, Tumblr, YouTube, and Snapchat, probing for information about the nature of the respondent's overall online presence. The second was an online/library examination of the respondent's academic and professional profile, including interviews/videos published online, her academia.edu profile, her researchgate.edu profile, and her published papers, in order to ascertain a sketch of her professional life. These two investigations provided a rich profile of the

DOI: 10.1039/C6RP00252H

respondent and how she presents herself publically. This gave the interviewer an insight into the participants' priorities as well as opportunity to know enough about the respondent to be able to establish sincere rapport during the interview. For example, one respondent frequently posts pictures of herself at sporting events, which gave the interviewer the opportunity to ask her about her favourite team, and then to briefly establish a commonality between interviewer and respondent (both supported a particular football team). In addition, patterns of publications emerged and were charted in order to prepare for discussions about productivity and expectations.

The interviews were audio recorded with two separate devices, and the researcher did not take any notes during the interview other than ticking off items that had been discussed on the interview schedule. Field notes were recorded manually both before and after the interview, in an effort to capture both the participants' environments and their non-verbal communication. Participants were emailed an information sheet and consent form prior to the interview, and before the interview began, both the respondent and researcher signed the consent form together and reviewed the purpose of the interview. The participants' anonymity was assured, and participants were offered copies of the researcher's ethics approval (none wanted to see it).

As a result of time limits, not all the items on the schedule could be explored. The excess questions were then distributed via an online survey created on surveymonkey.com. An additional Likert item was added to that survey, based on discussions generated during interviews. Three of the four participants completed the online survey. Please see the appendix for the interview schedule and online follow-up survey.

Analysis

The interviews were then transcribed by the researcher and uploaded into Nvivo, a qualitative data analysis software program distributed by QSR International. Primary categories for coding were generated from codes and themes in the literature, and labelled 'Provisional' codes (Creswell & Creswell, 2013; Dey, 1993), and utilized deductively, i.e., the codes were established prior to coding and the researcher looked for data which matched the code. For example, 'Critical Mass' was used as a deductive code, one exemplar of which is the following:

> …they have maybe 18 people where they used to have about 25 or something, but six of those 18 are women. And so they've kind of reached a critical mass within the department and now, everyone's just a colleague, it's not, 'Oh, she's a woman scientist' and 'he's a scientist.' [Beth]

As coding continued, more and more specific codes arose: emotion codes for moments that explored intra- and interpersonal experiences and relationships (Goleman, 1996; Kahneman, 2012; Prus, 1996), values codes for moments that explored principles, priorities, and beliefs (Gable & Wolf, 1993; LeCompte, Preissle, & Tesch, 1993), and versus codes for binary oppositional concepts, positions, etc., in conflict (Saldaña, 2014; Wolcott, 1994). These codes were utilized inductively, i.e., as several participants commented on a similar issue, a code was created to represent that issue. For example, 'Disillusionment,' was used to code moments when the respondent spoke about feeling like science, their position or their career path was not what they'd hoped it would be:

> So I did feel at lots, at lots of low times felt like I definitely can't, I definitely can't do this, I can't understand what, every time I get a paper I just can't understand the words in the abstract, I can get into this at all. [Ella]

The categories were then organised into themes, which helped to explain how participants have achieved success. All transcripts were read, analysed, and discussed by multiple researchers for internal validity via coding agreement. In addition, the data were triangulated with open-ended items answered in the online follow-up survey. External validity was established through agreement of results with published literature, and other

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DOI: 10.1039/C6RP00252H

members of the gender in science education research community. The data were thus established as both valid and reliable.

Theoretical Framework

Although this study is largely exploratory, it was approached from a definitively constructivist ontology. As such, the interviews were treated as sessions in which the participants' narrative was co-constructed by the participant and interviewer. The interviewer, in employing feminist interviewing techniques, tried to establish fluidity in hierarchy and power, embedding herself as both an assistant and a guide in creating the participants' stories and encouraging the participants to direct the narrative. The data were treated as viewpoints, rather than facts, and commonalities between viewpoints are presented in this paper. The interviewer positioned herself somewhat between the 'believing the interviewee' stance, in which all responses are taken at face value (Oakley, 1981), and scientific scepticism to follow up vague or contradictory statements (Abel, 1981; Andersen, 1981; Reinharz, 1992). In this way, the interviewer felt that she was guiding and questioning the participants in a way that was familiar and comfortable to them as women and as chemists.

Data were analysed using several theoretical lenses that are constructivist in origin: gender performativity with a Foucauldian interpretation. Most influential on data analysis were the works of Judith Butler and Rosalyn Diprose (Butler, 1990; Diprose, 2005), especially in the interpretation of data referring to dominant discourse and identity formation. Whilst there is no blame implied by the following data interpretation, neither is there agency, in that the researchers acknowledge that the majority of identity work and gender performativity noted in this paper were done subconsciously.

Results and Discussion

Analysis of the data showed that there were four significant factors common to the participants that helped the participants both to participate and stay in academic chemistry. First was a well-established support network in both her personal and professional life; second was a series of methods used to establish stability, both in job security and geographical location; third was the participants' choice to participate in particular niches, or subfields, which added to her stability and possibly decreased her exposure to gender bias; and last was the variety of ways in which the participants coped with gender bias and discrimination. Each of these will now be discussed in turn.

Support Network

Analysis of the data showed that a significant factor that was perceived to keep these women as practising scientists was the support they received during their careers. This support arose from four key areas. Firstly, support they received before going to University. Secondly, personal support from their families at crucial moments in their careers. Thirdly, mentoring and academic support they received from colleagues and supervisors and, fourthly, crucial careers advice they received from mentors or supervisors which had the effect of easing their way from student to professional academic.

Firstly, each of the women interviewed reported a lifelong love for science that began before or during primary school and solidified in university as a love for chemistry. They also reported feeling supported and encouraged by family, friends, and teachers to do what they loved, rather than being pushed toward or discouraged from a particular subject. These results are in agreement with other interviews in the literature which detail a wide variety of pre-University support networks that help women to achieve their bachelor's degree in STEM fields (De Welde et al., 2011; Lent et al., 1994; Robnett, 2015). The women in this study then went on to describe how two separate but integrated forms of support at a critical moment in their careers have helped them to become successful: personal and professional support.

Secondly, personal support emerged in several forms, often in the form of a partner/spouse or parent, but frequently in friends who were also academics; all of which encouraged the respondent to stay in the field and to do what they loved, no matter how difficult the path may have seemed at that moment. The moments described were perceived as pivotal moments in the participants' careers that would likely have affected their careers in fundamental ways had they not had that kind of personal support. Ella discussed the logistic difficulties of interviewing for her first tenure track position whilst breast-feeding, and the whole-hearted support her partner gave to support her application:

> My husband had to take those days completely off work…I remember, the interview schedule was on two pages, and down the margin I'd got: feed, sleep, nappy, feed, sleep, nappy, in like, the timeslots…I had to be at this bench…which was like the closest place to the interviews that was private-ish, like, behind this bush. Meet my husband, have the baby, breast-feed the baby, give her back (all rushed). She'd be crying and I'd just have to leave her there and just go back and do the next thing. [Ella]

While this situation may seem like co-parenting, the husband described was involved in time-sensitive research that was put on hold in order to become the primary care-taker for their child during his wife's interviewing (she was on maternity leave, he was working). Ava describes her personal support as less active, but as effective, especially when making a decision about whether or not to take action in the face of potential conflict:

> I guess I've kind of sometimes been hesitant to take action. I think my husband is far more forthright than I am. So, he sometimes encourages me to 'get over it, do something about it' which is good for me. [Ava]

For all participants, personal support provided a reliable safety net and they link this support to their feelings that they were doing well, having fun doing the science, and would have no trouble in moving to the next professional level, especially during the transition to their first academic post. Unlike a loss of self-efficacy reported in the literature (Grunert & Bodner, 2011b; Kuck & Marzabadi, 2007), the participants in this study had moments of doubt, but overall remained relatively confident in their abilities.

Thirdly, analysis from the findings suggested that participants perceived that most of the support they received from their mentor was social, in that their mentor found ways to increase their productivity by making their working environment comfortable. The literature suggests that better mentoring and academic support would be helpful in retaining women in chemistry (Kuck & Marzabadi, 2007; London, Downey, Romero-Canyas, Rattan, & Tyson, 2012; Moss-Racusin, Dovidio, Brescoll, Graham, & Handelsman, 2012; Nolan, 2006). The participants in this study all reported positive mentoring at the early stages of their career as integral to their success. These mentors were doctoral supervisors or departmental early-career mentors, and were all male. Charlotte's doctoral mentor reaffirmed her decision to pursue an academic pathway after a negative experience working as a research assistant; when asked about her mentor, she said, "I immediately felt at home in that lab. The group was about 10 plus or minus and it was a kind of family unit. So I went to the pub with him on the first Friday." She went on to describe him as nurturing and concerned with her progress. Ella describes her mentor as her hero, and in trying to resolve her social difficulties in her laboratory, she notes, "So [he] had another lab… and because I was just not getting on well in his group [here], he quite often said, "do you want to just go there?" And so I spent long periods of time in his lab [there], and that I really really enjoyed." In both cases, and for all participants, their early mentors seemed to function simultaneously as social mediators and safe social spaces, and as academic guides, with a greater emphasis placed on the ways in which the mentor managed to make these women feel welcome.

Fourthly, some of the participants (but not all) felt that their mentor was also effective in helping them to navigate their career path, by encouraging them to apply

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for grants, funding, fellowships, or other positions for which they might not have applied without their mentor's encouragement. Ava reported that her mentor was a positive influence, stating, "Definitely. He's incredibly supportive and finds all these things for me to apply for that I'd never seen." During a difficult period when she wasn't sure whether she should continue on an academic pathway and was trying to explore options, Beth reports her mentor "…really did sit me down and give me a good talking to and say, "No, look, this is what you should be thinking of doing, you should be applying for these independent fellowships, and etc." At the moment when Beth felt like she was wavering in her determination and almost ready to leave academic chemistry, this advice was crucial to her persistence. These case studies seem to imply that supportive and appropriate mentorship is indeed essential to retaining women in academic chemistry.

The support networks that were so integral to the participants' continued interest and participation in chemistry seemed to be most helpful in normalising the participants' marginality. The participants' interest in chemistry, in physical science, was gender-disruptive, since chemistry is often associated with males (Kelly, 1985). Instead of facing normalising judgement for the 'male' performance exemplified in their interest in chemistry, the participants received encouragement to continue their 'male' performance. Further, as they incorporated their 'male' performance into their gender identity, they developed an ambivalent gender identity: their professional identity was predominantly male, and encouraged to be so, whilst their personal identity was predominantly female, as indicated by their notion that they were primarily responsible for childcare. The ambiguity in their gender identity may be one of the key reasons why these participants have been so successful thus far: the literature indicates that the best leaders are those who are simultaneously masculine (i.e., aggressive, definitive) and mindful (i.e., feminine and nurturing) (Eccles, 1987; Kawakami, White, & Langer, 2000).

In summary, the findings above seem to demonstrate that there were a number of people in their lives supporting them to achieve success and not just one. What each of the participants described was a combination of friends and family, mentor, and international colleagues as their support network. This study challenges other studies that advocate for better academic mentoring as a key element to retaining women in chemistry (Kuck & Marzabadi, 2007; Laursen & Weston, 2014; Miller et al., 2014; Nolan, 2006); this study would suggest that an institutional push to revamp academic mentoring is only one possible part of a more complex network of support that needs to be instituted. Instead, it may be more effective to focus on the whole person and the need for support both at work and at home.

Stability

In addition to the need for support both at home and at work, analysis of the data showed that a second significant factor that was perceived to be important in keeping these women as practising scientists was their ability to cope with systemic instability throughout the progression of their careers. The participants' experiences with instability were likely similar to others throughout Science, but they have coped with the obstacles presented and managed to find ways to ensure stable home and work lives for themselves, and therefore maintaining or advancing their positions in academic chemistry. The need for stability was mentioned within two main contexts. Firstly, a key reason that participants perceived that women left chemistry research was to seek job security, which can be summarised as having a reliable position and salary. Secondly, the participants were concerned with the need to relocate to another laboratory, as is common in academic chemistry, and what that would mean for their families. These two concerns were often conflated, as they were perceived to be inextricably tied to each other.

Whilst in school and university, none of the participants seemed to have a good idea of where a degree in chemistry might take them, and they all reported that the majority of their university cohort left academic chemistry for various reasons, but mostly to seek job security elsewhere. All of the participants commented on the instability they faced at their first transitionary step toward a career in academic chemistry, and all noted the difficulties they faced in finding funding, in feeling secure in their position, and feeling as though they had a definite future in academia:

> And the guy I was working with over here wanted me to come back and do a post-doc afterwards, so, and then failed to apply for any funding, but still wanted me to come, so I applied for various fellowships, and I got…a…fellowship. That gave me three years of funding. So, I came over for that, and then, about two years into that, that was when I had a really big wobble, like "I'm really not sure if this is what I want to be doing." I thought about all sorts of other things, and I really was ready to just leave academia and do something else, I was just fed up with it. [Beth]

The frustration at not having a definite position or secured funding, and the subsequent financial and career worries that stem from this uncertainty could have been sufficient reason to leave academic chemistry. For the participants in this study, their worry was mitigated by their proactiveness: none of the participants has ever applied for only one funding opportunity, nor relied on anyone else for their funding. Every respondent reported that they coped with uncertainty by being acutely aware of available opportunities and has made it a priority, even before the science, at times, to constantly search out possibilities for funding. It may be true that most academics do the same, but the attitude of the participants toward funding may be a factor in helping them to achieve success. All of the participants report applying to multiple sources (for funding and for positions), and respond to rejection similarly; they all minimise the importance of rejected applications and emphasise the value of one acceptance.

In addition, most of the participants found their first academic positions funded through fellowships. They discussed applying for multiple fellowships, etc., but frequently understated the effort made by their former supervisors/mentors to secure them a place at the university for their fellowship: "He was like "Okay, we'll go for proper fellowships" and then that then led on to supporting me to apply for the fellowships that I have subsequently got." [Charlotte] 'Proper fellowships,' which all the participants had as their first academic posts, are awards given directly to the individual, who must have space to work, in a mentor's lab and with the mentor's resources (Barton, 2008). Their mentors clearly wanted to work with them, which suggests that the participants' network, and networking skills, had another kind of importance to that previously mentioned.

Relocation was also frequently mentioned whilst discussing instability in academia. Whilst all of the participants recognised that having children would present difficulties in time management, their greater concern was providing a stable home for their children. Because the international nature of science often requires researchers to work in a variety of laboratories in order to progress their work and attend international conferences several times per year, each respondent was concerned about their children or potential offspring having a safe and secure two-parent home and a dependable routine.

> You know, scientists are expected to be mobile, internationally mobile, for a couple of years between their doctoral thesis and then their academic job. It would be normal to work in a couple of different countries before you take up your job. It's just so hard to launch yourself into that at a time when you might be, you might have a partner and you might be thinking about having children, and even if you haven't, you think, I might want to and so how am I going to combine those things. [Ella]

For most of the participants, geographic stability was vital to staying in chemistry, as they had family in a particular region and/or their partners' jobs were based in a city and did not allow for working remotely. In addition, the presence of family allowed for childcare, without which

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the participants would be unable to work the hours necessary for their research. The participants implied that staying in one area within one country is dependent on one's ability to occupy a particular niche in chemistry, that is, only those chemists who have reliable funding and sufficient opportunity can choose where they will take a position. The participants tended to target institutions in one area and network for support and therefore a post at those institutions. They were frequently familiar with established scientists in their field, and those scientists were acquainted with them and their work, due to the fact that their subfields are both newly established and sparsely populated.

The participants' need to establish themselves in secure long-term positions was an indication of their professional 'male' performance, a reflection of the stereotype of male as the financial support for the family. The participants' feminine identity, as indicated by their descriptions of 'mother's guilt' (guilt felt by working mothers for not being 'ideal' mothers and staying at home with their children) disrupted their 'male' performances (Fortin, 2005; Poduval & Poduval, 2009). The disruption served to affect their 'male' performance, making it more 'male,' that is, more aggressive and determined to find the position that was more convenient to them and their families.

In summary, the findings above indicate that the participants' experiences were not dissimilar to others in science, but that they negotiated these experiences adeptly through coping strategies that employed their skill at networking and organisation. Their relationships with their supervisors and/or mentors were crucial to securing them a post, and their patient and proactive attitudes towards applying for funding and posts were essential in acquiring a fellowship. At a moment of high female attrition in chemistry (Chapman et al., 2011), the participants were able to persist in their careers through their support networks, active coping, and judicious choices about shifting their research into young and innovative subfields as will be shown in the next section.

Importance of the Subfield

Analysis of the findings showed that a third significant factor that was perceived to keep these women as practising chemists was their ability to be creative and innovative, and to carve out a niche, or subfield, for herself within a newer research area. Each respondent has established her expertise within relatively new subfields, for example, by applying the experimental technique she used in previous research in ways that hadn't been previously conceived or by reimagining mechanisms and pathways and initiating a new way of looking at an established phenomenon. Originally, the shift each respondent made to her current subfield was intended to help her gain independence, by breaking away from the work she did in conjunction either with her doctoral supervisor or her early-career mentor. For some participants, the shift in subfield resulted in the acquisition of a fellowship or grant funding; for others, it helped to define her as a scientist within the international community:

> That's another piece of absolutely standard advice to people on an academic career path: don't do what your supervisor does, do something really really different. And I do now, do something really different. I use the same technique, but I study such an entire, I mean, we would never meet at a conference anymore, because we work in such different areas. [Ella]

As each respondent modified her research in an effort to distinguish herself, she perceived that she gained intellectual independence within a unique subfield. Each of these subfields is new to chemistry and therefore does not carry the burden of tradition or social construct within its hierarchy. These new spaces are still in the process of formation and definition; as a result, they are relatively gender-neutral areas without 'founding fathers' or well-established methodologies or boundaries:

> And so it's, I think in the area of physical chemistry that I'm in, possibly because there's no money it (laughing) so no one is fighting for industry funding or things like that… some people do get some of that but it's to supplement the main funding, so

DOI: 10.1039/C6RP00252H

> everyone works together, everyone is incredibly supportive, and there's a lot of really successful collaborations. It's a lovely field. [Ava]

The subfield seems to provide these women with a working environment that relies on collaboration and transparency, which is in opposition to many other fields in science, in which misconduct is frequently acknowledged ("The BMJ Publishing Group Ltd," 2016)[2]. This type of environment, which does not require one to protect one's intellectual property, seems to allow the participants to focus on the science and achieve more than they might if they had to simultaneously focus on their science and social environment.

In addition, a subfield small enough that the senior scientists all know each other and tend to collaborate is one that leans toward traditionally female-associated traits: support and collaboration (Ahlqvist et al., 2013; Carli et al., 2016; Casey, 1996; Diekman et al., 2010; Halpern, 1997). In this respect, the subfields seem to be female-friendly, though still in their infancies. The participants are amongst the founding members of their respective subfields, and, as such, are in the unique position to set the ethos and praxis of the subfields for generations to come. As one of few in a subfield, the participants seem to be in high demand, meaning that they were able to both target a geographical location and be offered a post there and they seem to have positions that are as secure as possible in chemistry. These two factors have given the participants a rather unique sense of stability, one that seems to be somewhat reliant on her subfield and her position within that subfield. The subfields themselves are concerned with possibility rather than practicality: they were, for the most part, more concerned with pushing the boundaries of what is known rather than directly being applied to the betterment of humanity. This is a somewhat curious finding, in that previous research implies that women will seek out and participate in scientific research that is nurturing, productive, and that helps living beings (Ceci et al., 2014; Diekman et al., 2010), whilst this study shows that some of the most successful young chemists have sought out fields that expand humanity's understanding of nature, but do not necessarily have any immediate benefit. The contrast between the general environment of the subfields (collaborative) and the subject matter (theoretical) may create a gender confusion that gives the participants the freedom to simultaneously be both 'woman' and 'chemist.' In other words, because these women do not seem to struggle, on an everyday basis, with unconscious or overt bias, they may have the opportunity to simply be the women they are whilst doing the science they love. In this environment, the participants were able to incorporate their 'male' performance and feminine identities into one aggregate without encountering normalising judgement for their 'male' performance. Whilst their identities were and always will be in flux, the participants' chosen subfields provided a safe space in which their identities could be relatively constant. Both the culture of the subfield and the stability it provided the participants helped to keep them in chemistry. However, they must interact with the whole of the department, and the participants had gender-biased experiences in the greater department, even if they did not within their niche or subfield.

Bias and Discrimination

Analysis of the findings showed that whilst these participants experienced significant bias and discrimination in their jobs, much like other gendered bias and discrimination reported in the literature (See for example, Laursen & Weston, 2014a; Moss-Racusin et al., 2012; Robnett, 2015), they nevertheless had developed powerful coping strategies which kept them in the profession. They had four key ways of coping with this bias and discrimination: firstly through distancing themselves from it, and secondly, through adoption of dominant ways of thinking. These two coping mechanisms represent the ways in which the participants did not fight bias with which they have had to contend. The

[2] The BMJ and others have publically available information on misconduct in science and scientific publishing because misconduct happens often enough to warrant it. Articles on specific cases of misconduct may be found in almost every science-related magazine and science section of major newspaper.

third coping mechanism was confirmation, especially in the case of 'woman' as 'mother,' in which the participants accepted and defended stereotypes. Fourthly, there was a coping strategy which involved an active denial of bias and discrimination by some of the participants, which could be called a presentation of proof, in which the participants voluntarily (without prompting) offered evidence in opposition whilst implicitly acknowledging conventional stereotypes. The third and fourth coping methods were both active and resistant ways in which the participants fought against bias.

Firstly, the participants in this study sought to distance themselves from instances of discrimination. Each respondent began her interview by discussing how important she believed it was to address gender bias in chemistry. However, they all then claimed there was no overt sexism in their subfields, but that they did encounter bias and discrimination in a variety of ways within their departments and greater fields. This initial distancing implied a safe space from bias on an everyday basis. That is, within the subfield, in which the participants spend most of their time, they insisted there was neither discrimination nor bias. They claimed that they were aware of 'these things happening,' but that they were never directly involved with any incidents. When pressed, it appeared that they actually were victims of gender discrimination, but that most of these experiences occurred within the department or university setting, rather than the laboratory or classroom. For some of the participants, there was a general understanding of the continued existence of gender bias in chemistry and in the department:

> You know, people like to recruit people who are like themselves, that's well known. And, um, people tend to think of people as being clever if they see their own image in the chair. Often, scientific esteem is measured in all sorts of fuzzy ways and that includes the authority that people exude when they're in seminars and this kind of thing, and that's often a male trait. But of course you can't generalise — there are plenty of women who exude authority all over the place — but normally it's men. [Ella]

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All of the participants seemed to be aware of the gendered bias generally associated with science, and, more specifically, with instances of discrimination in their department. Distancing themselves from the bias, as a coping mechanism, can be understood as complicity in recreating and perpetuating gender barriers; the participants are identifying as discursively 'male' through their passively reductive description of bias. In their characterisation of 'hearing about' bias happening in the department, they reduce bias to rumour rather than fact, and thereby perform 'male' (Rhoton, 2011). In addition, they tended to further distance themselves from instances of gender discrimination by discussing experiences as either theoretical or in third person narratives, describing them as happening to a friend or colleague, or excusing discriminatory behaviours in some way.

Excusing the bias lead to the second key coping mechanism of adopting dominant ideology; excusing biased rhetoric and behaviours was common to all participants, and the ways in which they did so varied. For the most part, they called the verbal harassment they encountered 'harmless' and therefore not worth the trouble of upset or of reporting the incident to the proper authorities:

> You get various things, you know. Comments about various parts of my anatomy, or something like that, which are not meant in a... Not nasty comments, or really disturbing comments, or anything like that. Just throw away comments…It's absolutely not anything that I would kind of raise as, this person's being a sexist or whatever, because that's definitely not how it's intended, but you know…[Beth]

This particular type of justification could be attributed to two different theories: silencing, or adoption. According to London, et. al., women in academia may cope with gender-based threat by self-silencing, or suppressing her own feelings about experiences in order to maintain relationships and prevent rejection. Further, gender-based rejection, and sensitivity towards it, reinforces self-doubt, decreases self-efficacy and confidence, and increases the probability that harassment will go unreported for fear of retaliation (London et al., 2012). This could be the case for the participants in this study; they chose to cope with gender-based threat/rejection by distancing themselves from it through silence and justifying their silence by saying that the verbal harassment wasn't meant to be malignant. This coping mechanism is similar to accounts of 'laddish' behaviour, which reduces instances of discursive or symbolic violence to 'banter,' indicating that bias should be seen as playful rather than offensive (Phipps, 2016; Phipps & Young, 2013). If indeed the participants meant to indicate that the bias they experienced was 'laddish' behaviour and should be dismissed as banter, they were then identifying themselves as performing 'male' by condoning and disregarding the harassment. On the other hand, it could be that chemistry is currently undergoing the problem delineated in the Etzkowitz, et. al., theory of the paradox of critical mass (Etzkowitz et al., 1994); women in most chemistry departments have reached a critical mass (at least at the junior levels) and have now factioned off into two groups—the more experienced women unconsciously associate themselves with male-patterned bias against women, whilst the less experienced women try to find equity in their professional lives. This is the second key coping mechanism the participants used to deal with discrimination: adoption; all of the participants displayed their unconscious bias *against* women on a number of occasions, thus revealing themselves as aligned with a male-associated ideology. This ideology—the dominant way of thinking--assumes that a woman's place in society is the same as it has been for many long years: her primary responsibilities are to procreate, care for the children, organise and care for the home, and care for her husband.

> Yeah. In principle, [women are] equal, but I think the realities of life make women less likely to choose work intensive careers… [Women] feel the urge, need, whatever to maintain a stable family environment. [Charlotte]

The participants reiterate this ideology, insisting that there is a way to *perform* femininity, to act like a woman that conflicts with acting like a chemist, and they reaffirm the notion that the home and children are primarily a woman's responsibility. Some of the participants go on to indicate that in their interactions with other female chemists, they perform the male-ness of their critical mass faction, emphasising ambition and selfishness rather than the typical female attributes of compassion, cultivation, and contribution:

> I think that side of things, that actually you do need to look out for number 1, and nobody else is going to do it, and I didn't realize that until far too late, I really should've realized that a lot earlier [Beth]

The participants are unconsciously siding with the forces of ideology that seek to undermine them by virtue of their gender, and the sanctioning of their complicity in subjugating junior women to this form of ideology is rewarded by promotion and, eventually, success. Bias is institutionalised in chemistry, constantly being performed, taught, learned, and then acted out by a new generation. But this does not imply that the participants' internalisation of bias has not generated internal conflict for them; adopting a male-associated bias did not necessarily extend to their ideas about their personal lives, especially in the case of motherhood, thus their continued struggle with an ambivalent gender identity, defined by disruption and nuance.

The third key coping mechanism was confirmation, in which the participants acknowledged and then defended stereotypes about parenting. All of the participants seemed to associate 'woman' with 'mother,' and 'mother' with primary parenting responsibilities. As they all identified as 'women,' these ingrained associations seemed to cause discomfort for them in terms of both bias and their identities. It was during their discussions of family that they revealed how they each constantly renegotiate their identities, simultaneously battling between internalised male-associated 'chemist' and a lifelong ideologically ingrained understanding of 'woman.' Whilst each respondent clearly loves her family and, when pushed, would choose her family over her career, there was also a bit of resentment and disappointment that the

DOI: 10.1039/C6RP00252H

concept 'having it all' was somewhat unrealistic. None of the participants felt as though maternity leave should be swapped for paternity leave (meaning that the mother goes directly back to work whilst the father/other parent stays at home with the newborn), but they were all frustrated or angry in speaking about the inherent issues involved with taking a substantial amount of time off, and with the need to stay close to home after that:

> …since having children, I stopped, I essentially stopped going to conferences. I went to, I now have a quota of going, I allow myself a quota of going to one or two a year, maximum. I go overseas once a year for a conference. But I have probably 20 invitations a year to talk overseas, and I just turn them all down. So, that's a sacrifice for example, because all of those things would lead to esteem, higher esteem, you know, everybody knows you, you've been invited, you know. As long as you make a good job of it, then it increases your, it benefits your career in all sorts of ways. [Ella]

All of the participants spoke about the ways in which having children (both now, for the mothers and in future, for those thinking about children) directly affects their external esteem, and were somewhat defensive in their assertion that having children *should not* be detrimental to one's career and that there were institutional-level policies that could be enacted in order to prevent this:

> Going all the way through, I never ever saw being a woman scientist being an issue at all until, certainly after I got a lectureship, and it's been since then that I've kind of noticed it. And actually I've been very very dismissive of the "women in science" agenda and all the rest of it for the majority of my career, I would say, and it's only really the last 5-10, probably not even 10 years, 5 years, that I have realized that there actually are still issues. There's the obvious kind of "having kids" one, and that is always going to be an issue. There are lots of things that could be done to make that easier that aren't being done. [Beth]

Placing the onus for this particular kind of discrimination on the institution seemed to mitigate the participants' own responsibility for its propagation; were the participants to disassociate woman from 'mother,' and all that 'mother' ideologically implies, the professional ramifications of having children might fall equally on both parents. Instead, the participants accepted and defended the historically laden term of 'mother,' confirming gendered divisions of labour and their own internalised concept of 'woman' (Afiouni & Karam, 2013; Leskošek & Vesna, 2011). As such, they seemed to unconsciously and automatically defend their dual position as 'woman' and 'chemist' by providing proof that they have earned their success.

The fourth key coping mechanism was where the participants implicitly acknowledged gender stereotypes by providing proof that she is intellectually and physically capable of not just doing her job, but excelling in chemistry. In chemistry, as in most scientific fields, external esteem is arguably the most essential component to quantifying one's level of success. According to the participants, external esteem can be measured in many ways, but invitations to give keynotes, paper citations, and one's appearance of authority within one's field are examples of such measures. It is these factors, among others, that determine who is given grant funding, promotions, and a host of other honours and distinctions (see 'Ella' quote above). One of the ways in which the participants' need for external esteem surfaced was in descriptions of their undergraduate activities and academics, with several participants repeatedly emphasizing their degree classifications, although they were never asked for this information. This repetition may indicate that she has indeed faced some measure of gendered intellectual bias, and subconsciously feels as though she needs to prove her academic merit (Grunert & Bodner, 2011a; Halpern, 1997; Halpern & LaMay, 2000). Moreover, most of the participants have had an experience in which she has felt the need to 'prove herself' in some way to a member of her department or greater field:

> …I needed some particular tool and I went down to the main workshop and I found the head of the workshop…I asked for this thing by name, can I borrow *this*. And I basically got the Spanish inquisition in return. It was like, all, 'well, what

> do you want that for? Do you know how to use it? Does your supervisor know that you're going to use this? Are you sure you don't want to just put a job into workshop?' Meanwhile, this is going on and I thought very clearly stating that yes I did know what it was and I did know how to use it, all the rest, and he just kept going. And then there was another PhD student kind of wandered in, and was like "Oh, [Joe], you know that widget you lent me last week, can I borrow it again?" and [Joe] dutifully trotted off and came back with said widget and handed it to him and he walked out. And he took one look at me and I think just realized how differently he treated the two of us, and he just turned around, went out, got what I wanted, came back, gave it to me; never had another problem. And it was the same sort of thing here, so I just felt that I had to prove my competence, rather than having it assumed, and once I have proved my competence, it's never a problem after that, I've had no trouble at all. I just think the blokes don't have to do that, people just assume they know how to use a spanner. [Beth]

Except for Beth (quote above), most of the participants who had had a similar experience, generally in dealing with traditionally male-dominated areas, such as mechanics, dismissed the incidents as non-significant and spoke about them with a certain sense of pride—as if they'd passed an exam. For them, it was an experience that could have happened to any student or early-career researcher--it was not at all because they were women, and it was explained to the interviewer as such. In the moment, the participants likely understood the incident to be gendered, but from their present positions, they describe it as a negotiation of power or age and experience. This is both a coping mechanism and a representation of their current outlook and gendered associations. The participants cope with the incident by excusing it as a misunderstanding, that once the mechanics (or whomever) understood their competence, it was never again questioned. On the other hand, from their current perspective and the ways in which they were constructing their life history during the interview, the male assumption that basic tools mystify females is subsumed into their now male-associated unconscious bias, and that experience, which was pure sexism, metamorphoses into a legitimate question of experience.

Implications and Conclusion

The participants in this study seem to have experienced the gender gap in similar ways to other women in science, as reported in the literature, but have developed and enacted sophisticated coping mechanisms that have helped them to achieve success thus far. The depth of the life history interview provided a rare glimpse into how a woman may achieve success in chemistry as well as insight into the sacrifices, compromises, and negotiations she must navigate and endure in order to do so. The results from the cases in this study resonated with the literature at times, reinforcing the notions that women in science cope with particular kinds of gendered stresses and behaviours in specific ways; efforts can be made to help ameliorate their work environment and increase recruitment of women into chemistry: better and more creative career counselling, support, and a conscious effort to address bias (Commission, 2012; Dabney & Tai, 2014; Miller et al., 2014; Robnett, 2015, etc.). However, the women in this study have also found a novel method of coping by creating a niche/subfield. While this finding could not be replicated in *every* scientific field, in chemistry it is a viable and inventive way of creating a novel work environment that can be equitable in ways that more established fields cannot. In addition, the literature seems to favour the idea of critical mass rectifying gendered issues within an academic department, but this study suggests that critical mass is by no means a solution to the problems. Instead, the findings imply that some successful women, by adopting a male-associated bias, may become a part of the larger problem of gender bias. Key findings representing well-rounded support networks, establishment of stability, choice of subfield, and coping mechanisms for bias imply that there are actions that may be taken in order to increase both the number of women who choose to participate in chemistry as well as the proportion of women who stay in chemistry.

Firstly, for the results that are in agreement with the literature, it seems clear that policies need to be established that require primary and secondary schools to not just teach chemistry, but to establish the field of chemistry as gender-neutral. Tweens and teenagers have already incorporated unconscious bias into their understanding of the world, and have already associated chemistry with maleness (Easterly & Ricard, 2011; European Commission, 2012). Any break with this association will help the next generation into accepting and working toward gender equality in chemistry and the other sciences. Replicating these interventions—bias training and factors that have helped others succeed—at the undergraduate and then postgraduate levels would be useful, as they would emphasise positivity and agency rather than reactionary resources like counselling or tutoring. Supportive networks, both within the department and the lab group, and in one's personal life, seem to be effective in helping women to persist in chemistry (Birgeneau, 1999; European Commission, 2012; Kuck & Marzabadi, 2007; Lewis & Richmond, 2010; Robnett, 2015). Most of the literature focuses on the need for academic support that is not just equitable in frequency and access, but is the kind of support that 'women' need—gentler, kinder, less aggressive (Kuck & Marzabadi, 2007; Robnett, 2015). This study implies that there is a need to extend support to networks (Dabney & Tai, 2014; Robnett, 2015), and to help women analyse their current situations and the role personal support plays in their success so they can monitor that for themselves. In essence, it may be wise for universities to take small steps to be certain that their future academic chemists (and others) are as supported as possible—as an investment in the future of the university and in chemistry. Investing in the future may also come in the form of periodic unconscious bias training for staff, students, and faculty, as confronting bias will provide insight into their own predilections and practices. In this way, it may be possible to slowly shift ingrained unconscious bias within chemistry departments towards a more gender-inclusive atmosphere, as well as repair the rupture that produces the two opposing factions of women, those who have adopted male-associated bias and those who have not, within the department.

Secondly, the newer results have other implications for policy and practice. First, there is very little in the literature that addresses women's needs for job stability in chemistry, or even in science or STEM. Nor does the literature address the ways in which there is a specific kind of stability that is needed for these fields because of the particular demands for international movement in these fields. The global scientific community may have reached a point in time at which it is possible to work closely with groups overseas without moving (or moving one's family) every few years. The technological age has brought ease of communication with it, and in an attempt to both support scientists' personal lives and give them the advantage of working with a wide variety of people in their fields, remote working could be considered as an alternative to moving around the globe. In addition to relieving the stress of moving, remote work might mitigate other concerns with regard to space and kit; universities and principal investigators/professors/group leaders would know exactly how much space and money they have, and would not constantly have to juggle allocations each term.

The participants in this study were enabled in their success, in part, by their choice of subfield and the novelty of that subfield. Their ability to navigate the subfield and form alliances that aided them was crucial to their success. Whilst it would be impossible to be specific about the subfields (as it would compromise anonymity), the subfields are *newer* fields, fields that have broken off from the mainstream due to a shift in application, subject, or methodology. It is in these newer spaces that the participants in this study seem to thrive, having found a space that is accessible and open to them and less afflicted with traditions and practices stemming from gender bias. It is, however, clear that bias is still so active and influential in chemistry that it is possible that the participants' success could *only* be achieved in 'blank slate' subfields, in which they imagine they are seen first as scientists and then as women. It is feasible that subfields, which have not yet set a 'norm,' may be one of the few areas in chemistry in which women may perceive themselves as doing just that. The participants tend to describe their fields in terms of conceptual proximity to either biology or physics, indicating both ambiguity about the conceptual heart and nature of chemistry (as opposed to biology—science of life—or physics—study of matter) and their own alignment with male-dominated or under-represented minority ideologies and gender bias. Those participants who described their subfield as physics-related tended to adopt male-dominated gender bias, whereas those participants who were more biology leaning tended to feel the effects of bias a bit more sharply.

Overall, it would seem that flexibility in gender identity, with an inclination towards 'masculine and mindful,' could be a key aspect in women achieving success in chemistry. Coping with an ambivalent gender identity and performing gender appropriately seem to be mitigated by supportive friends, family, mentors, and colleagues. In addition, newer subfields seem to be better environments for performing ambiguous gender. In light of these findings, breaking down the barriers of stereotype and gender expectation would be helpful to women in chemistry; it is, however, unlikely that stereotype or expectation could be banished completely from society. It may be constructive to instigate awareness of and sensitivity to non-binary gender associations, thereby recognising and encouraging the nuance in gender identity that has helped the participants achieve success.

With the establishment of a variety of departmental or institutional policies, it is likely that women's retention in chemistry could likewise improve, thereby creating a woman-friendly or gender-neutral environment that is almost solely focussed on science. This type of environment would not only be beneficial to female chemists, but may be constructive in pushing chemistry beyond current knowledge at an increased pace. There are limitations to this research: this is a multiple case study of four participants, in very different subfields within the greater field of chemistry. Whilst their stories differ somewhat, they also have much in common, and this paper focuses on those commonalities. What this study suggests is that there is a need to investigate women's experiences in fields and then subfields within science, and STEM, in order to fully understand the current situation and how it may be ameliorated for the future recruitment and retention of women. Similar studies in biology and physics are currently under investigation and results from these will be published in due course.

References

Abel, E. (1981). Collective Protest and the Meritocracy: Faculty Women and Sex Discrimination Lawsuits. *Feminist Studies*, *7*(3), 505. http://doi.org/10.2307/3177762

Afiouni, F., & Karam, C. M. (2013). Structure, agency, and notions of career success A process-oriented, subjectively malleable and localized approach. *Career Development International*, *19*(5), 548–571. http://doi.org/10.1108/CDI-01-2013-0007

Ahlqvist, S., London, B., & Rosenthal, L. (2013). Unstable Identity Compatibility How Gender Rejection Sensitivity Undermines the Success of Women in Science, Technology, Engineering, and Mathematics Fields. *Psychological Science*, *24*(9), 1644–1652. http://doi.org/10.1177/0956797613476048

Andersen, M. L. (1981). Corporate Wives Longing for Liberation or Satisfied with the Status Quo? Happy Housewives or Women with the Blues? *Urban Life*, *10*(3), 311–327.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). "Doing" science versus "being" a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Science Education*, *94*(4), 617–639.

View Article Online
DOI: 10.1039/C6RP00252H

http://doi.org/10.1002/sce.20399

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). "Balancing acts": Elementary school girls' negotiations of femininity, achievement, and science. *Science Education*, *96*(6), 967–989. http://doi.org/10.1002/sce.21031

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice Hall.

Bandura, A. (2001). Social Cognitive Theory: An Agentic Perspective. Retrieved April 10, 2014, from http://www.annualreviews.org/doi/pdf/10.1146/annurev.psych.52.1.1

Bandura, A., Barbaranelli, C., Caprara, G. V., & Pastorelli, C. (2001). Self-efficacy beliefs as shapers of children's aspirations and career trajectories. *Child Development*, *72*(1), 187–206. http://doi.org/10.1111/1467-8624.00273

Bandura, A., & Locke, E. a. (2003). Negative self-efficacy and goal effects revisited. *The Journal of Applied Psychology*, *88*(1), 87–99. http://doi.org/10.1037/0021-9010.88.1.87

Barton, G. J. (2008). The UK Academic System: hierarchy, students, grants, fellowships and all that. Retrieved from http://www.compbio.dundee.ac.uk/ftp/pdf/The_UK_Academic_system.pdf

Basford, T. E., Offermann, L. R., & Behrend, T. S. (2013). Do You See What I See? Perceptions of Gender Microaggressions in the Workplace. *Psychology of Women Quarterly*, *38*(3), 340–349. http://doi.org/10.1177/0361684313511420

Birgeneau, R. J. (1999). *Women Faculty in Science at MIT :* (Vol. XI). Cambridge, MA, USA.

Bøe, M. V., Henriksen, E. K., Lyons, T., & Schreiner, C. (2011). Participation in science and technology: young people's achievement-related choices in late-modern societies. *Studies in Science Education*, *47*(1), 37–72. http://doi.org/10.1080/03057267.2011.549621

Butler, J. (1990). *Gender Trouble: Feminism and the Subversion of Identity*. New York: Routledge.

Calabrese Barton, A., Kang, H., Tan, E., O'Neill, T. B., Bautista-Guerra, J., & Brecklin, C. (2012). Crafting a Future in Science: Tracing Middle School Girls' Identity Work Over Time and Space. *American Educational Research Journal*, *50*(1), 37–75. http://doi.org/10.3102/0002831212458142

Carli, L. L., Alawa, L., Lee, Y., Zhao, B., & Kim, E. (2016). Stereotypes About Gender and Science: Women = Scientists. *Psychology of Women Quarterly*, *40*(2), 0361684315622645-. http://doi.org/10.1177/0361684315622645

Casey, M. B. (1996). Gender, Sex, and Cognition: Considering the interrelationship between biological and environmental factors. *Learning and Individual Differences*, *8*(1), 39–53.

Ceci, S. J., Ginther, D. K., Kahn, S., & Williams, W. M. (2014). Women in Academic Science: A Changing Landscape. *Psychological Science in the Public Interest*, *15*(3), 75–141. http://doi.org/10.1177/1529100614541236

Ceci, S. J., & Williams, W. M. (2011). Understanding current causes of women's underrepresentation in science. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(8), 3157–62. http://doi.org/10.1073/pnas.1014871108

Chapman, S., Dixon, F. F., Foster, N., Kuck, V. J., McCarthy, D. A., Tooney, N. M., … Marzabadi, C. H. (2011). Female faculty members in university chemistry departments: Observations and conclusions based on site visits. *Journal of Chemical Education*, *88*(6), 716–720. http://doi.org/10.1021/ed100098q

Clancy, K. B. H., Nelson, R. G., Rutherford, J. N., & Hinde, K. (2014). Survey of Academic Field Experiences (SAFE): Trainees Report Harassment and Assault. *PLoS ONE*, *9*(7), 1–9.

http://doi.org/10.1371/journal.pone.0102172

Creswell, J. W., & Creswell, J. W. (2013). *Qualitative inquiry & research design : choosing among five approaches*. SAGE Publications.

Dabney, K. P., & Tai, R. H. (2014). Factors Associated with Female Chemist Doctoral Career Choice within the Physical Sciences. *Journal of Chemical Education*, *91*, 1777–1786.

Dabney, K. P., Tai, R. H., Almarode, J. T., Miller-Friedmann, J. L., Sonnert, G., Sadler, P. M., & Hazari, Z. (2012). Out-of-School Time Science Activities and Their Association with Career Interest in STEM. *International Journal of Science Education, Part B*, *2*(1), 63–79. http://doi.org/10.1080/21548455.2011.629455

Danielsson, A. T. (2012). Exploring woman university physics students "doing gender" and "doing physics." *Gender and Education*, *24*(1), 25–39. Retrieved from http://ezproxy-prd.bodleian.ox.ac.uk:2108/doi/abs/10.1080/09540253.2011.565040#.VMdzvVqZbww

De Welde, K., Laursen, S. L., & Gulf, F. (2011). The Glass Obstacle Course : Informal and Formal Barriers For Women Ph . D . Students in STEM Fields The Glass Obstacle Course : Informal and Formal Barriers For Women Ph . D . Students in STEM Fields. *International Journal of Gender, Science and Technology*, *3*(3), 571–595.

Dey, I. (1993). *Qualitative data analysis : a user-friendly guide for social scientists*. (Routledge, Ed.). New York, NY.

DiBenedetto, M. K., & Bembenutty, H. (2013). Within the pipeline: Self-regulated learning, self-efficacy, and socialization among college students in science courses. *Learning and Individual Differences*, *23*, 218–224. http://doi.org/10.1016/j.lindif.2012.09.015

Diekman, A. B., Brown, E. R., Johnston, A. M., & Clark, E. K. (2010). Seeking congruity between goals and roles: a new look at why women opt out of science, technology, engineering, and mathematics careers. *Psychological Science*, *21*(8), 1051–7. http://doi.org/10.1177/0956797610377342

Diprose, R. (2005). *The Bodies of Women: Ethics, Embodiment and Sexual Differences*. New York: Routledge.

Easterly, D. M., & Ricard, C. S. (2011). Conscious Efforts to End Unconscious Bias: Why Women Leave Academic Research. *Journal of Research Administration*, *XLII*(1), 61–73.

Eccles, J. S. (1987). Gender Roles and Women's Achievement-Related Decisions. *Psychology of Women Quarterly*, *11*(2), 135–172. http://doi.org/10.1111/j.1471-6402.1987.tb00781.x

Etzkowitz, H., Kemelgor, C., Neuschatz, M., Uzzi, B., Etzkowitz, H., Kemelgor, C., … Alonzo, J. (1994). The Paradox of Critical Mass for Women in Science Published by : American Association for the Advancement of Science The Paradox of Critical Mass for Women in Science, *266*(5182), 51–54.

European Commission. (2012). *Meta-analysis of gender and science research*. Brussels.

Fortin, N. M. (2005). Gender Role Attitudes and the Labour-market Outcomes of Women across OECD Countries. *Oxford Review of Economic Policy*, *21*(3), 416–438. http://doi.org/10.1093/oxrep/gri024

Fouad, N. A., & Smith, P. L. (1996). A Test of a Social Cognitive Model for Middle School Students : Math and Science. *Journal of Counseling Psychology*, *43*(3), 338–346.

Fraser, J., Shane-Simpson, C., & Asbell-Clarke, J. (2014). Youth science identity, science learning, and gaming experiences. *Computers in Human Behavior*, *41*, 523–532. http://doi.org/10.1016/j.chb.2014.09.048

Gable, R. K., & Wolf, M. B. (1993). *Instrument development in the affective domain : measuring attitudes and values in corporate and school settings*. Boston: Kluwer Academic Publishers.

Geary, D. C. (1995). Sexual selection and sex differences in spatial cognition.

Learning and Individual Differences, *7*(4), 289–301.
Goleman, D. (1996). *Emotional intelligence : why it can matter more than IQ*. London: Bloomsbury.
Greene, J., Stockard, J., Lewis, P., & Richmond, G. (2010). Is the Academic Climate Chilly? The Views of Women Academic Chemists. *Journal of Chemical Education*, *87*(4), 381–385.
Grunert, M. L., & Bodner, G. M. (2011a). Research and Practice Finding fulfillment : women's self-efficacy beliefs and career choices in chemistry. *Chemistry Education: Research & Practice*, *12*, 420–426. http://doi.org/10.1039/c1rp90050a
Grunert, M. L., & Bodner, G. M. (2011b). Underneath it all : gender role identification and women chemists ' career choices. *Science Educational International*, *22*(4), 292–301.
Halpern, D. F. (1997). Sex differences in intelligence. Implications for education. *The American Psychologist*, *52*(10), 1091–102. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/9329293
Halpern, D. F., & LaMay, M. L. (2000). The Smarter Sex: A Critical Review of Sex Differences in Intelligence. *Educational Psychology Review*, *12*(2), 229–246. http://doi.org/10.1023/A:1009027516424
Harding, S. (1986). *The Science Question in Feminism [Paperback]*. Ithaca, New York, USA: Cornell University Press; Reprint edition. Retrieved from http://www.amazon.co.uk/Science-Question-Feminism-Sandra-Harding/dp/0801493633/ref=sr_1_1?ie=UTF8&qid=1397151539&sr=8-1&keywords=the+science+question+in+feminism
Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, M.-C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*, *47*, n/a-n/a. http://doi.org/10.1002/tea.20363
Hazari, Z., Tai, R. H., & Sadler, P. M. (2007). Introductory University Physics Performance : The Influence of High School Physics Preparation. *Gender and Education*, *91*(6), 847–876. http://doi.org/10.1002/sce
HESA - Higher Education Statistics Agency - HESA - Higher Education Statistics Agency. (2016). Retrieved February 1, 2015, from https://www.hesa.ac.uk/component/content/article?id=103&ItemId=141&limit=&start=0
Higher Education Statistics Agency. (2016). Data collection | HESA. Retrieved from https://www.hesa.ac.uk/collection
Hobbs, S. V, Holland-minkley, A. M., & Millett, L. I. (1999). A Case for Building Inclusive Research Communities as an Integral Part of Science and Engineering Graduate Education. In *Women and Technology: Historical, Societal, and Professional Perspectives* (pp. 80–89). New Brunswick, NJ: IEEE.
Hughes, G. (2001). Exploring the Availability of Student Scientist Identities within Curriculum Discourse: An anti-essentialist approach to gender-inclusive science. *Gender and Education*, *13*(3), 275–290. http://doi.org/10.1080/09540250120063562
Hunter, A.-B., Laursen, S. L., & Seymour, E. (2007). Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. *Science Education*, *91*(1), 36–74. http://doi.org/10.1002/sce.20173
Irving, P. W., & Sayre, E. C. (2013, June 3). Physics identity development: A snapshot of the stages of development of upper-level physics students. *Journal of the Scholarship of Teaching and Learning*. Retrieved from http://josotl.indiana.edu/article/view/3521
Jackson, P. A., & Seiler, G. (2013). Science identity trajectories of latecomers to science in college. *Journal of Research in Science Teaching*, *50*(7), 826–857. http://doi.org/10.1002/tea.21088
Jahren, A. H. (2016, March 4). She

Wanted to Do Her Research. He Wanted to Talk "Feelings." *New York Times*, p. SR4. New York.

Johnson, A., Brown, J., Carlone, H., & Cuevas, A. K. (2011). Authoring identity amidst the treacherous terrain of science: A multiracial feminist examination of the journeys of three women of color in science. *Journal of Research in Science Teaching*, *48*(4), 339–366. http://doi.org/10.1002/tea.20411

Kahneman, D. (2012). *Thinking, fast and slow*. London: Allen Lane.

Kawakami, C., White, J. B., & Langer, E. J. (2000). Mindful and Masculine: Freeing Women Leaders From the Constraints of Gender Roles. *Journal of Social Issues*, *56*(1), 49–63. Retrieved from http://onlinelibrary.wiley.com/store/10.1111/0022-4537.00151/asset/0022-4537.00151.pdf?v=1&t=j5mn8ypn&s=5201e14d75b446b84d27b977ee058fd105e592f4

Kelly, A. (1985). The Construction of Masculine Science. *British Journal of Sociology of Education*, *6*(2), 133–154. http://doi.org/10.1080/0142569850060201

Korpershoek, H., Kuyper, H., van der Werf, G., & Bosker, R. (2011). Who succeeds in advanced mathematics and science courses? *British Educational Research Journal*, *37*(3), 357–380. http://doi.org/10.1080/01411921003671755

Krogh, L. B., & Andersen, H. M. (2012). "Actually, I May be Clever Enough to do it". Using Identity as a Lens to Investigate Students' Trajectories Towards Science and University. *Research in Science Education*, *43*(2), 711–731. http://doi.org/10.1007/s11165-012-9285-2

Kuck, V. J., & Marzabadi, C. H. (2007). A Review and Study on Graduate Training and Academic Hiring of Chemists, *84*(2), 277–284.

Lancaster, K. (2016). Confidentiality, anonymity and power relations in elite interviewing: conducting qualitative policy research in a politicised domain. *International Journal of Social Research Methodology*, 1–11. Retrieved from http://dx.doi.org/10.1080/13645579.2015.1123555

Laursen, S. L., & Weston, T. J. (2014). Trends in Ph.D. Productivity and Diversity in Top-50 U.S. Chemistry Departments: An Institutional Analysis. *Journal of Chemical Education*, *91*, 1762–1776.

LeCompte, M. D., Preissle, J., & Tesch, R. (1993). *Ethnography and qualitative design in educational research*. San Diego: Academic Press.

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a Unifying Social Cognitive Theory of Career and Academic Interest, Choice, and Performance. *Journal of Vocational Behavior*, *45*(1), 79–122. http://doi.org/10.1006/jvbe.1994.1027

Leskošek, & Vesna. (2011). Historical Perspective on the Ideologies of Motherhood and its Impact on Social Work. *Social Work & Society*, *9*(2).

Leslie, S.-J., Cimpian, A., Meyer, M., & Freeland, E. (2015). Expectations of brilliance underlie gender distributions across academic disciplines. *Science*, *347*(6219), 262–265. http://doi.org/10.1126/science.1261375

Lewis, P., & Richmond, G. (2010). Women Academic Chemists. *Journal of Chemical Education*, *87*(4), 381–385.

Lock, R. M., Hazari, Z., & Potvin, G. (2012). Physics career intentions: The effect of physics identity, math identity, and gender. In *Physics Education Research Conference* (pp. 262–265). American Institute of Physics. http://doi.org/10.1063/1.4789702

London, B., Downey, G., Romero-Canyas, R., Rattan, A., & Tyson, D. (2012). Gender-based rejection sensitivity and academic self-silencing in women. *Journal of Personality and Social Psychology*, *102*(5), 961–979. http://doi.org/10.1037/a0026615

MacDonald, A. (2014). *"Not for people like me?" Under-represented groups in science, technology and engineering*. Bradford, UK. Retrieved from https://www.wisecampaign.org.uk/upl oads/wise/files/not_for_people_like_me.pdf

Miller, A., Dowd, J., Heath, D., Metcalfe, S., Morris, D., Moseley, S., … Williams, R. (2014). *House of Commons - Science and Technology Committee - Sixth Report*. London. Retrieved from http://www.publications.parliament.uk/pa/cm201314/cmselect/cmsctech/701/70102.htm

Morgan, S. L., Gelbgiser, D., & Weeden, K. A. (2013). Feeding the pipeline: Gender, occupational plans, and college major selection. *Social Science Research*, *42*(4), 989–1005. http://doi.org/10.1016/j.ssresearch.2013.03.008

Moss-Racusin, C. A., Dovidio, J. F., Brescoll, V. L., Graham, M. J., & Handelsman, J. (2012). Science faculty's subtle gender biases favor male students. *Proceedings of the National Academy of Sciences* , *109*(41), 16474–16479. http://doi.org/10.1073/pnas.1211286109

Newsome-Lober, J. (2008). *The chemistry PhD: the impact on women's retention*. Retrieved from www.rsc.org/diversity

Nolan, S. A. (2006). Gender Disparity in the Training and Mentoring of Chemists. In C. H. Marzabadi, V. J. Kuck, S. A. Nolan, & J. P. Buckner (Eds.), *Are Women Achieving Equity in Chemistry?* (pp. 29–44). Washington, D.C.: American Chemical Society.

Nosek, B. a., & Smyth, F. L. (2011). Implicit Social Cognitions Predict Sex Differences in Math Engagement and Achievement. *American Educational Research Journal*, *48*(5), 1125–1156. http://doi.org/10.3102/0002831211410683

Nudzor, H. P. (2013). Interviewing Ghanaian Educational Elites : Strategies for Access , Commitment , and Engagement. *International Journal of Qualitative Methods*, *12*, 606–623.

Oakley, A. (1981). Interviewing women: a contradiction in terms. In H. Roberts (Ed.), *Doing feminist research* (p. 207). Routledge & Kegan Paul.

Olitsky, S. (2007). Facilitating identity formation, group membership, and learning in science classrooms: What can be learned from out-of-field teaching in an urban school? *Science Education*, *91*(2), 201–221. http://doi.org/10.1002/sce.20182

Phipps, A. (2016). (Re)theorising laddish masculinities in higher education. *Gender and Education*, 1–16. http://doi.org/10.1080/09540253.2016.1171298

Phipps, A., & Young, I. (2013). *That's what she said: Women students' experiences of "lad culture" in higher education*. London. Retrieved from http://sro.sussex.ac.uk/49011/1/That's_what_she_said_full_report_Final_web.pdf

Poduval, J., & Poduval, M. (2009). Working mothers: how much working, how much mothers, and where is the womanhood? *Mens Sana Monographs*, *7*(1), 63–79. http://doi.org/10.4103/0973-1229.41799

Pomeroy, C. (2015). Academia's Gender Problem. *Scientific American*, *314*(1), 11–11. http://doi.org/10.1038/scientificamerican0116-11

Prus, R. C. (1996). *Symbolic interaction and ethnographic research : intersubjectivity and the study of human lived experience*. Albany, NY: State University of New York Press.

Reinharz, S. (1992). *Feminist methods in social research*. Oxford University Press.

Rhoton, L. A. (2011). Distancing as a gendered barrier: Understanding Women Scientists' Gender Practices. *Gender & Society*, *25*(6), 696–716. http://doi.org/10.1177/0891243211422717

Robnett, R. D. (2015). Gender Bias in STEM Fields: Variation in Prevalence and Links to STEM Self-Concept. *Psychology of Women Quarterly*, *40*(1), 0361684315596162-. http://doi.org/10.1177/0361684315596162

Sadler, P. M., Almarode, J. T., Miller-Friedmann, J. L., Tai, R. H., Sonnert, G., Hazari, Z., & Dabney, K. P. (2012). Out-of-School Time Science Activities and Their Association with Career Interest in STEM. *International*

Journal of Science Education, Part B. http://doi.org/10.1080/21548455.2011.629455

Saldaña, J. (2014). *The coding manual for qualitative researchers* (3rd ed.). London: SAGE Publications Ltd.

Selwyn, N. (2012). Researching the once-powerful in education: the value of retrospective elite interviewing in education policy research. *Journal of Education Policy*, *28*(3), 339–352. http://doi.org/10.1080/02680939.2012.728630

Sinnes, A. (2006). Three Approaches to Gender Equity in Science Education. *NorDiNa*, *2*(1), 72–83.

Smith, D. E. (2006). *Institutional Ethnography as Practice*. Lanham, Maryland: Rowman & Littlefield Publishers, Inc.

Smith, E. (2011). Women into science and engineering? Gendered participation in higher education STEM subjects. *British Educational Research Journal*, *37*(6), 993–1014. Retrieved from http://ezproxy.ouls.ox.ac.uk:2073/stable/23077020

Smith, E., & White, P. (2014). What makes a successful undergraduate? The relationship between student characteristics, degree subject and academic success at university. *British Educational Research Journal*, *41*(4), 686–708. http://doi.org/10.1002/berj.3158

Spencer, S. J., Steele, C. M., & Quinn, D. M. (1999). Stereotype Threat and Women's Math Performance. *Journal of Experimental Social Psychology*, *35*(1), 4–28. http://doi.org/10.1006/jesp.1998.1373

Stewart, K., Gill, P., Chadwick, B., & Treasure, E. (2008). Qualitative research in dentistry. *BDJ*, *204*(5), 235–239. http://doi.org/10.1038/bdj.2008.149

"The BMJ Publishing Group Ltd." (2016). Scientific misconduct | The BMJ. Retrieved August 15, 2016, from http://www.bmj.com/about-bmj/resources-authors/forms-policies-and-checklists/scientific-misconduct

Walford, G. (2012). Researching the powerful in education: a re-assessment of the problems. *International Journal of Research & Method in Education*, *35*(2), 111–118. http://doi.org/10.1080/1743727X.2012.669523

Wilson, Z. S., McGuire, S. Y., Limbach, P. A., Doyle, M. P., Marzilli, L. G., & Warner, I. M. (2014). Diversifying science, technology, engineering, and mathematics (STEM): An inquiry into successful approaches in chemistry. *Journal of Chemical Education*, *91*(11), 1860–1866. http://doi.org/10.1021/ed400702v

Wolcott, H. F. (1994). *Transforming qualitative data : description, analysis, and interpretation*. Thousand Oaks, CA: Sage Publications.

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APPENDIX: Interview Schedule and Online Follow-Up Survey

Part I: Interview Schedule

Early Childhood

1. When and where were you born?
2. What did you imagine you'd be when you 'grew up'?
3. Did you imagine you'd have children, lots of money, fame, etc.?
4. When did you become interested in science?
5. How would you, as a little girl, have described a scientist?
6. Did you have any science hobbies? (school-related or original?) Did you belong to science clubs or groups?
7. Who was the most influential person to you as a child? Why?
8. What did your parents do for work? If they were scientists, what kind of scientist? Did this influence your interest in science?
9. Did you feel like your parents were supportive? Did they want you to become a scientist? Were they disappointed that you didn't go into another (which?) field?
10. (Was your community supportive?)
11. Did you 'fit in'? If not, how did you cope?

Education

12. What was your favourite subject to study?
13. Is there a teacher or another adult that you remember having been particularly influential? + or -? Encouraged/discouraged?
14. How would you describe yourself as a student, both socially and academically?
15. What sort of extracurricular activities did you participate in as a teen?
16. Did anyone ever tell you that you excelled in a subject? Which subject? How did that make you feel? Did it change your career aspirations?
17. Where did you attend university? Why did you choose that university?
18. What subject(s) did you study and why?
19. If you could do it again, would you take a different academic path, or are you satisfied with the route you followed? Which field and why?
20. Did your whole cohort in Uni persist to become scientists? To which fields did they go? When did they change? Why do you think they changed fields?
21. Did you feel like there were subjects meant for girls and others meant for boys?
22. Was there any evidence of gender discrimination in your field? Personal discrimination?
23. Did you feel like you were just as intelligent as everyone else in your cohort? Were you as academically prepared as they were?

Career

24. Please describe all the jobs/roles you have had in your career.
25. Did you ever have a mentor? Male/female? Helpful?
26. When did you start calling yourself a 'scientist'?
27. Were there many women in your first lab group?
28. What kinds of expectations and/or limitations were placed on you in each job/role? Who placed these expectations and/or limitations on you? (
29. Looking back, how do you feel about the opportunities you have had? How do you feel about the opportunities you missed, or were not made available to you?
30. How would you describe your employers' attitudes towards you?
31. Did you experience gender discrimination?
32. Do you feel like you've been promoted less than your male counterparts?

Family

33. Do you have children? If so, how many and what age and gender are they?
34. Would you encourage your children to go into science? Why/why not?
35. Did you feel like having a family hindered your career in some way? Were provisions made for you so that you could have children and continue along your career path (maternity leave, breastfeeding space, childcare)?

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Life Events

36. What, if anything, would you have done differently in your life?
37. What do you know now that you wish you'd known when you were young?
38. Have you ever been given advice that you've held onto and remembered?
39. How do you define success?
40. What would you like future generations to remember about you?
41. Do you feel like gender stereotypes are different now to what they were when you were a child?

Part II: Online Follow-Up Survey

Note: Items 1-5 and 7 were open-ended, essay type questions; Item 6 was a 6-point Likert-Scale question; Item 8 was a fill-in-the-blank question.

1. Do you feel like gender stereotypes are different now to what they were when you were a child?
2. Do you feel like your field is different now to when you first began your career?
3. What do you think the turning points have been in your life?
4. In what ways is it important to know your limitations in your life or career?
5. Describe a person or experience that has had a profound effect on the way you look at the world.
6. How much of your success would you attribute to luck, and how much would you say is due to hard work?
7. Now that you've had time to think and reflect on what we discussed, is there anything you'd like to add, amend, or say differently? Is there anything you think you should have said, but didn't? Is there anything you'd like to add to what we discussed in our interview? Was there anything we said that you thought about after our interview?
8. Please indicate the date of our interview: DD/MM/YYYY