The chemistry PhD: the impact on women's retention

A report prepared by Jessica Lober Newsome for the UK Resource Centre for Women in SET and the Royal Society of Chemistry

RSC | Advancing the Chemical Sciences

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Since 1841, the RSC has been a leading society and professional body for chemical scientists, and is committed to ensuring that an enthusiastic, innovative and thriving scientific community is in place to face the future. The RSC has a global membership of over 46,000, with a further 300,000 associated chemical scientists internationally, and is actively involved in the spheres of education, qualifications and professional conduct. It runs conferences and meetings for chemical scientists, industrialists and policy makers, at both national and local level. It is a major publisher of scientific books and journals, the majority of which are held in the RSC Library and Information Centre. In all its work, the RSC aims to be objective and impartial, and is recognised throughout the world as an authoritative voice of the chemical sciences.

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About the UKRC

The UKRC for Women in SET works to significantly improve the participation and position of women in science, engineering and technology occupations in industry, research, academia, and public service to benefit the future productivity of the UK and the lifetime earnings and career aspirations of women. It is the UK's leading Centre providing information and advisory services to employers and organisations in the SET sectors and supporting women entering, returning and progressing in these fields.

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Foreword by the Chair of the RSC Science Policy Board

I am delighted to present the findings of this study examining the experiences of students studying for their PhDs in chemistry. I am also pleased to be able to acknowledge the fruitful collaboration between the UK Resource Centre for Women in Science Engineering and Technology (UKRC) and the Royal Society of Chemistry (RSC).

The collaboration came about after Annette Williams, the UKRC's Director, heard some preliminary data from a survey of chemistry PhD students presented at the Royal Society. The data in question suggested that during the chemistry PhD women progressively changed their minds about pursuing a career in research. The obvious question was, "Why is this happening?"

When later the UKRC found they had some funds available they approached the RSC to ask if we wanted to try to answer this question. Naturally we were delighted and we set up the joint project.

The findings presented in this report back up the survey findings that women have less satisfactory PhD experiences than men. Women are less likely to want to pursue research after completing their studies and this lays down some challenges for chemistry.

Chemistry has developed a good reputation for improving working practices in chemistry departments as evidenced by the fact that Edinburgh Chemistry Department was the first UK department to receive a silver Athena SWAN award in 2006 and, at the time of writing, York Chemistry Department is the only UK academic department to have been awarded a Gold SWAN. I am confident that if my colleagues apply good practice principles to improving the PhD experiences of men and women more of our PhD graduates will want to stay in the laboratory.

Professor Lesley Yellowlees MBE BSc PhD FRSC
Chair, RSC Science Policy Board
Head of School of Chemistry, The University of Edinburgh

Foreword by the Director of the UK Resource Centre for Women in SET

I am delighted to present the findings of this research on the experience of doctoral study in chemistry and the relationship this has to PhD students' intentions to continue with a research career. This research project was carried out by the Royal Society of Chemistry (RSC) in collaboration with the UK Resource Centre for Women in Science Engineering and Technology (UKRC).

The UKRC has a primary objective to foster women's engagement and progression in science. Therefore understanding the impact of the experience of doctoral study on the career intentions of female students in particular is important to the UKRC. One way of encouraging the retention of highly qualified women from Science, Engineering and Technology (SET) study and employment, is to find ways for organisations to support women at key life and career transition stages so that talented and qualified women are not lost from SET careers.

This study identifies factors related to the doctoral study experience that deter a larger proportion of women than men from remaining in research after they complete their PhDs. The findings from the study indicate that experience of the structures, cultures, environments and practices of scientific research plays a crucial role in influencing the career choices of research students. The take-home message is an important one. If the experience of doctoral study is disappointing, this can lead many women and men to view research careers in a negative light, especially research careers in academia. This is ultimately a loss to the UK's research base and to potential innovation.

After the executive summary you will find a list of policy recommendations based on the research findings. These suggest ways of improving culture and practice that will benefit doctoral students in chemistry and in the sciences in general. I hope that these recommendations will be taken forward by the appropriate stakeholders including Heads of SET university departments, all those who work and/or supervise PhD students, learned societies, and research councils because the changes the report suggests can only be accomplished with their support and enthusiasm.

The UKRC supports research that informs both policy and practice and has commissioned and funded a number of research projects such as this to constantly update the evidence base for work in this field. More information can be found on our website: www.ukrc4setwomen.org.

Annette Williams
Director, UKRC

Acknowledgements

This project was co-ordinated by Sarah Dickinson, Science Policy and Diversity Specialist, and Sean McWhinnie, Manager, Science Policy, both of the Royal Society of Chemistry. Key advisors to the project were Caroline Fox of the Athena Forum, Chris Kirk and Rebecca Smith of the Biochemical Society, Pat Morton of Sheffield Hallam University, and Louise Ackers of the University of Liverpool. The UKRC was represented by Anna Zalevski and Leigh Ingham.

The research was carried out by Jessica Lober Newsome.

This project would not have been possible without the co-operation of the staff in university chemistry departments who helped arrange focus groups, and the current and past PhD students who gave their time to take part in the focus groups or to be interviewed.

Thanks are also due to the UK Resource Centre for Women in Science Engineering and Technology (UKRC) who provided the opportunity and funding to carry out this study. Additionally, UKRC's help and advice throughout the project has been greatly appreciated.

Executive Summary and Key Findings

This research attempted to establish what accounts for the findings of a RSC survey of the career intentions of chemistry PhD students (RSC, 2008). It was a qualitative study which aimed to pin point the factors that discourage women more than men from planning a career in research, especially in academia.

81 chemists, via eight focus groups (six with second year students, two with third year students) and 47 telephone interviews (23 with third year students and 24 with people who had recently completed a chemistry PhD programme) participated in the research.

The research identified that the following factors, which relate to the doctoral study experience, and deter a larger proportion of women than men from remaining in research beyond their PhD.

During doctoral study, a larger proportion of female than male participants had:

- Been deeply affected by what might be termed 'standard supervision issues' (e.g. enjoying little pastoral care and having to cope with a supervisor who lacks interpersonal/management skills);
- Encountered significant supervision issues, which they felt powerless to resolve;
- Experienced a lack of integration with their research group, isolation and exclusion (and more rarely, bullying);
- Been uncomfortable with the culture of their research group (about working patterns, time and expectations and the level of competition between group members), especially where the culture was particularly 'macho';
- Developed concerns about poor (though normal) experimental success rates, apprehensive of what this may infer to others about their skills and competence;
- Formed the impression that the doctoral research process is an ordeal filled with frustration, pressure and stress, which a career in research would only prolong; rather than short-term pain for long-term gain.

The research suggested that where women do not wish to pursue an academic career, this is because they perceived the rewards on offer insufficient to overcome the challenge and compromise entailed.

In contrast to male participants, female participants had:

- Come to view academic careers as too all-consuming, too solitary and not sufficiently collaborative;
- Come to the conclusion that the short-term contract aspect of post-docing could not be reconciled with other aspects of their life, particularly relationships and family;
- Come to believe the competition for a permanent academic post was too fierce for them to compete successfully;
- Come to believe they would need to make sacrifices (about femininity and motherhood) in order to succeed in academia;
- Been advised in negative terms of the challenge they would face (by virtue of their gender).

The report concludes that the chemistry PhD programme and academic careers are modelled on masculine ways of thinking and doing, which leaves women neither supported as PhD students nor enthused to remain in research in the longer term. Cultural as well as procedural change is required to address this.

Policy Recommendations

The policy recommendations are based on the research findings. Each recommendation is followed by the names of the key stakeholder(s) (denoted by ➲) considered by the authors to be the most appropriate to take it forward. Although the recommendations are based on findings specific to chemistry, improvements in culture and practice will benefit students in any discipline and therefore the recommendations are equally applicable to other disciplines.

PhD Experience

- Consideration should be given to including the assessment of the PhD experience as part of the Athena SWAN award criteria to ensure that good working practices are established throughout all aspects of university departments' activities.

  ➲ Athena SWAN

- Some respondents reported feeling isolated during their PhD and this needs to be tackled. PhD students should be part of an appropriate research group wherever possible. Where PhD student research areas are not directly linked to a group, then students should be part of wider networks to ensure contact and support are maintained.[1]

  ➲ Universities; Chemistry Departments; UK Resource Centre for Women in SET

- An independent advisor/buddy system should be introduced for PhD students in their first year, especially those working in more isolated circumstances. Such a system will provide support for students through the provision of independent support which is particularly important for students who are frustrated by feelings that their research is not progressing.[2]

  ➲ Universities; Chemistry Departments

- Some participants felt that they struggled during their PhD. Several students reported difficulty getting results which led them to question whether there was any point in carrying on with research when nothing seemed to be working. Women in particular were more likely than men to have felt that the PhD had become an ordeal. To tackle this, a more supportive culture in respect of the development of individual PhD students needs to be developed in some chemistry departments; it is important to ensure that this change embraces all aspects of the department's culture. The culture change should make it normal practice that support is provided for students and that individual students' experiences are regularly monitored.[3] In particular, aspects of the current culture that affects women's desire to remain in chemistry research needs to be changed for the long-term benefit of individual PhD students and of chemistry.

  ➲ Universities; Chemistry Departments; RSC; UK Resource Centre for Women in SET

Supervision

- Focus group participants believed that in order for a student to have an overall positive experience of their PhD, it is imperative that he or she has a positive experience of supervision. Supervisors should have access to training to allow them to develop people management skills which incorporate equality and diversity considerations, as befits their role. A local pastoral care structure should be implemented by institutions, so that PhD students have someone to turn to, and to take the pressure off supervisors and post-doctoral fellows.[4]

  ➲ Universities; Chemistry Departments; UK Resource Centre for Women in SET

- The role that post-doctoral fellows play in supervision and support needs to be acknowledged and underpinned with appropriate training. PhD students spoke in positive terms about the support and advice

[1] See also the Quality Assurance Agency for Higher Education (QAA) Code of Practice, section 1: Postgraduate research programmes, QAA 2004, ISBN 1 84482 168 4, precept 5
[2] ibid, precepts 5 and 13
[3] ibid, precepts 15 and 16
[4] ibid, precept 13

that they received from post-doctoral fellows and how they provide a different perspective to that of a student's supervisor. Funding bodies should acknowledge this and support the role with time allowances. The supervision role undertaken should be seen as positive staff skill development.

➲ Universities; Research Councils

Good Practice

- Some female participants were discouraged from pursuing a research career by a lack of female role models who were seen to have a good balance between their family life and academic career, which seemed to imply to them that it is very difficult to do this. Measures are needed to demonstrate that women and men can pursue a successful research career in chemistry, as well as achieving work life balance. Good practice examples should be widely disseminated. These would include positive role models; examples of female and male academics who have balanced life and work successfully; publicising the good practice work of the RSC and other learned societies; promulgating models of working that allow career breaks for men and women without harming research careers.

  ➲ Universities; Chemical Industry; Chemistry Departments; RSC; UK Resource Centre for Women in SET

- Provision of master classes in gender awareness and good practice should be part of research conferences and subject specific gatherings.

  ➲ Learned Societies; UK Resource Centre for Women in SET; Research Councils

Monitoring

- Changes in departmental culture and in the career intentions of chemistry PhD students should be monitored through the repetition of surveys at appropriate intervals (say, every 3 years) to find out in particular whether students are better disposed towards research careers.

  ➲ RSC; UK Resource Centre for Women in SET; Universities.

[5] ibid, precept 21

[6] Most academic institutions are now surveying their doctoral students using the Postgraduate Research Experience Survey (PRES) survey tool developed by the Higher Education Academy. For further details, see: http://www.heacademy.ac.uk/ourwork/research/surveys/pres

1 Introduction

This report presents the findings of a collaborative research project between the UK Resource Centre for Women in SET (UKRC) and the Royal Society of Chemistry (RSC). The research comprised a combination of focus groups and telephone interviews with current and recently completed chemistry PhD students, which were carried out during Autumn2007/Winter 2008.

1.1 Project Drivers

Female retention in science, engineering and technology (SET) is an important issue, with economic and social justice implications. The overall retention rate of female SET graduates is far lower than that of males, 25% compared with 40%.[7] The situation, which contributes to the relative lack of women in senior positions in SET professions, is sometimes described as "the leaky pipeline"; as scientists flow along the science career pipeline – a notional path representing training and advancement – they 'leak out' and are lost to science.[8]

One aspect of the remit of the UKRC is to 'foster women's engagement and participation (in SET), focusing on key life and career transition stages' (UKRC Mission Statement). The provision of support for policy/practice-informing research which aims to improve female retention supports that goal. A focus on the PhD-contract research worker (CRW) transition is important as this is the point at which women leak from the science pipeline most (EC 2002).[9]

The RSC became interested in "the leaky pipeline" when analysis of Higher Education Statistics Agency (HESA) data showed that female attrition is notably higher in chemistry, compared with other sciences.[10] It was noted that, whereas chemistry and, for example, physics had significantly different proportions of female undergraduate students (at the time around 40% and 20% for chemistry and physics respectively), the proportion of female professors was the same (under 1% for both subjects at that time).

Moreover, it emerged from the data analysis that while similar proportions of men and women progressed from undergraduate to doctoral chemistry programmes, a significantly smaller proportion of women than men moved from PhDs to post-doctoral positions. The RSC commissioned a focus group study to examine why female chemists were less likely than male chemists to stay in academia after completing their PhDs.[11]

Further insights into female attrition from chemistry at the PhD-CRW stage were provided by the results of a survey of doctoral chemistry students (conducted by the RSC in 2006,[12] see www.rsc.org/diversity). Although the survey focused on the career intentions of PhD students, which can only predict their actual destinations to a certain extent, the survey revealed that, (a), unlike male chemists, many female chemists are put off further chemistry research during the course of their PhD studies and, (b), of those students intending to stay in research, fewer female than male chemists want an academic career, especially in the longer term.

(a) As shown in Figure 1, the proportion of female chemistry PhD students who were planning a research career after finishing their PhDs fell over the course of doctoral study. 72% of first year but only 37% of third year female chemistry PhD students indicated they wanted to do research after their PhDs. This suggested that female chemistry PhD students re-think an intention to pursue a research career after their initial experience of doctoral study and/or research science. This pattern was not found among male chemistry PhD students. The proportion of male chemistry PhD students with an intention to pursue a research career fell only 2% from 61% among first years to 59% among third years. Moreover, the proportion of second year male PhD students wishing to stay in research actually increased from that in the first year to 73%. It is also interesting to note that a greater proportion of female (72%) than male respondents (61%) began their doctoral studies planning a career in research.

[7] Report for the Office of Science and Technology and the Department of Trade and Industry, Maximising Returns to Science, Engineering and Technology Careers. London: DTI, 2002.
[8] N. Angier, Women Swell Ranks of Science, But Remain Invisible at the Top. New York Times, May 21, 1991.
[9] European Commission/Strata-ETAN Working Group Human Resources in RTD: Benchmarking National R&D Policies. Brussels: European Commission, 2002.
[10] Factors affecting the career choices of graduate chemists, Royal Society of Chemistry: London, 1999.
[11] Ibid
[12] The Career Intentions & First Employment Destinations of Chemistry PhD Students: A Gender-Based Quantitative Analysis, Royal Society of Chemistry: London, 2008.

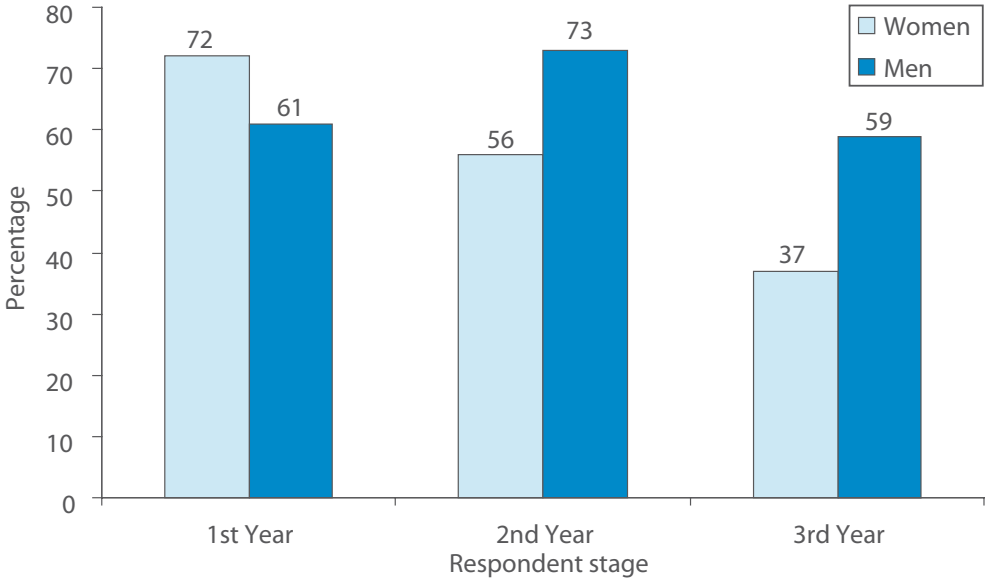

Figure 1: Proportion of respondents intending to pursue research on completing doctoral study by gender and stage

(b) Considering only the respondents who were intending to pursue a research career, female chemistry PhD students were less likely than male students to want to do so in academia (as opposed to in an industrial or public sector setting). 44% of men and 37% of women saw academia as a career option for them. As shown in Figure 2, the survey highlighted that there is a significant change in the attitude of female respondents between the first and second years: 53% of second year male respondents but only 29% of second year female respondents indicated they planned to continue in research in academia after completing their PhD even though a greater proportion of female respondents (51%) than male respondents (44%) began their doctoral studies planning to stay in academia. An interesting point to note (one which this report will return to) is that among men, the proportion of third year respondents planning to stay in academia decreased substantially to 36% from 53% between the second and third years. Overall 12% of third year women and 21% of third year men intended to pursue research careers in academia.

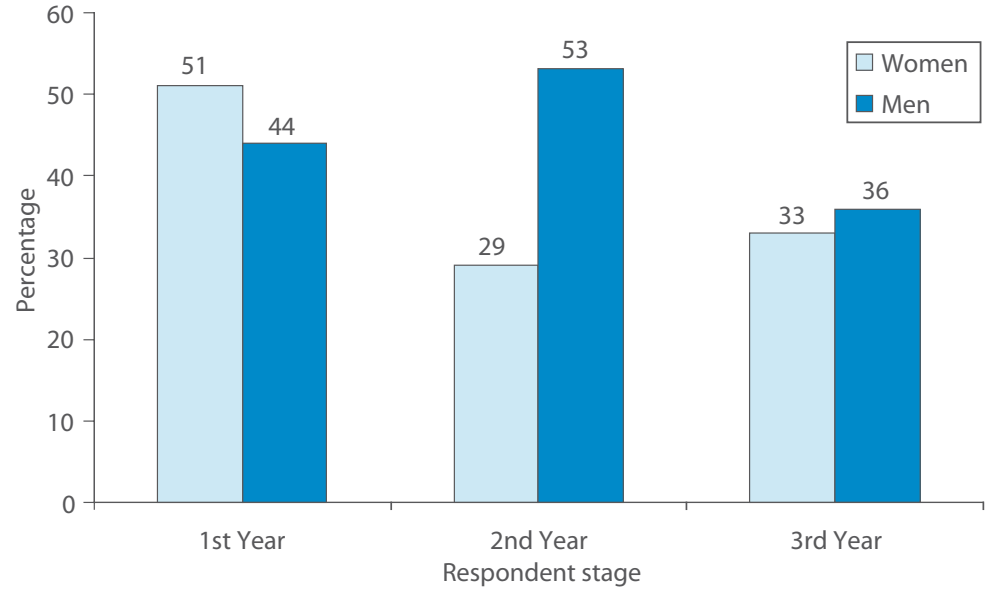

Figure 2: Proportion of respondents intending to pursue a research career who plan to do this in academia by gender and stage

The research presented in this report followed up the findings of the two surveys to identify the factors affecting the changes in attitude observed. The research methods used were individual interviews and focus discussion groups with current and recently completed chemistry PhD students. Qualitative responses to the open-ended questions in the 2006 survey had hinted that women were put off academia by what they described as the 'all-consuming' nature of academic research, by the isolation it entails, and by a perceived or real incongruity between an academic science/chemistry career and motherhood. What was deterring women from research was less evident from the qualitative responses. There was some indication that female respondents thought that there were drawbacks to certain aspects of research work (e.g. repetition, stress and solitude) whereas male respondents were concerned by the realities of the research-based labour market (e.g. pay levels and progression opportunities).

1.2 Project Aim

This project was concerned with the careers of chemists following their PhDs and the reasons why women are less likely to stay in research roles than men.

1.3 Project Questions

The project aimed to identify what accounts for the RSC 2006 survey findings that although a greater proportion of women than men in their first year of a chemistry PhD saw themselves remaining in research and staying on in academia, over the course of the PhD many women decided against pursuing chemistry further, especially in an academic setting (more women were put off academia than were put off research generally). The key research question was therefore:

What deters a greater proportion of female than male students from a career in, (a), research and, (b), academia, upon completion of their chemistry PhD?

It should be noted that it is not the intention to imply that all chemistry PhD students should aim for a career in research or academia.

2 Previous Studies

2.1 Gender and the Doctoral Study Experience

A key piece of research on the doctoral study experience in science was carried out in the United States by Etzkowitz *et al*.[13] This work, based on over four hundred interviews with female and male postgraduates and members of faculty, across five disciplines and 13 universities, strongly suggested that women are less likely to have a positive doctoral study experience than men. Etzkowitz *et al* argue that the maleness of the culture in academic science causes female science postgraduates to feel disorientated and lacking in direction, especially in the first years of their study, thus eroding their self-confidence. Yet, according to Etzkowitz *et al*, women rarely voice their difficulties to others for fear of being singled out and being labelled a feminist rather than 'one of the lads'. Furthermore, Kemelgor and Etzkowitz[14] contend that male scientists are most likely to enjoy informal social networks within academic science departments while by contrast women are more likely to experience exclusion, causing many to leave science at the earliest dignified opportunity.

2.2 The Leaky Pipeline

Two surveys regarding the leaky pipeline were highly relevant to this project. O'Driscoll and Anderson[15] provided evidence (relating to physics and biochemistry) that despite being very keen initially, women graduate students soon changed their minds about pursuing research further mainly because working in a laboratory usually necessitates a degree of remoteness from 'the outside world', and by the long working hours, which leaves little time for other interests. The women surveyed also believed it was hard for them to be taken seriously in such a male-dominated profession. Whitelegg *et al*[16] reported how only one in four of the young women physicists they had surveyed were still in scientific employment a few years after completing their PhD, despite having previously aspired to work in academic or research careers. Reasons given by respondents for leaving science included a dislike of the male culture or atmosphere, doubts they would ever attain a senior post, and concerns about balancing an early research career with a young family.

The focus group study commissioned by the RSC in 1999 involved four focus groups comprising final year postgraduates, post-docs and recently appointed lecturers, and two further groups comprising chemistry graduates working outside academia. The study investigated the reasons why female chemists were 'choosing' to leave academic chemistry departments in much greater proportions than men. The findings of that work were that while both sexes saw the '24-hour culture' of chemistry in academia as a major issue and were concerned about the pay and career structure for those who are not high-fliers, solely women were discouraged by:

- The loneliness of chemistry in academia, exacerbated by having to work in a predominately male culture, conditioned by male values;
- Poor working conditions in laboratories (health and safety, lack of equipment, lack of technical support);
- Too much emphasis on results rather than process in terms of research;
- Occupational sex segregation (horizontal segregation between disciplines and vertical segregation between grades);
- The expectation that it was virtually impossible for a woman to combine a fast-track career with having a family.

[13] H. Etzkowitz, C. Kemelgor, and B. Uzzi, Athena Unbound: The Advancement of Women in Science and Engineering. Cambridge: Cambridge University Press, 2000.
[14] C. Kemelgor and H. Etzkowitz, Overcoming Isolation: Women's dilemmas in American academic science, Minerva, 39, pp239-257, 2001.
[15] M. O'Driscoll and J. Anderson, Women in Science. Attitudes of university students towards a career in science: a pilot study. London: PRISM Unit for Policy Research in Science and Medicine, 1994.
[16] E. Whitelegg, B.K. Hodgson, E. Scanlon and C. Donovan, Young Women's Perceptions and Experiences of Becoming a Research Physicist, Proceedings of 12th International Conference of Women Engineers and Scientists, July 27-31, Ottawa, Canada. Paper reference no. 167, 2002.

3 Methodology

3.1 Overview

The project took a qualitative approach and used two methods: telephone interviews and focus groups. It was cross-sectional, rather than longitudinal, in design. Tables 1 and 2 provide overviews of the focus group and telephone interview elements respectively.

3.2 Ethical Considerations

The project was carried out in full accordance with the relevant guidelines set by the Social Research Association. Participants were given ethical assurances relating to informed consent, the right for a participant to withdraw consent at any stage, confidentiality and anonymity and the security of raw and derived data arising from the project. Focus group participants were asked to provide written participation consent while telephone interviewees were asked to give verbal participation consent.

Where direct quotes are reproduced in the report, pseudonyms are used and identifying circumstances have been disguised.

Quotations may have been edited for brevity.

3.3 Focus Groups

Eight focus groups with current chemistry PhD students (mainly second year PhD students in order to explore the apparent change of heart with regards to career intentions) were held in three university chemistry departments.

Departments were selected:

- Such that the sample would include a range of levels of commitment to 'good practice' in terms of fostering equality and diversity;
- Aiming for a spread in geographical location (Department 1 was in Southern England, Department 2 was in Northern England and Department 3 was in Scotland);
- On the basis that each was sufficiently large to provide the required number of participants.

Regrettably, however, difficulties were encountered in recruiting focus group participants, so most of the groups had fewer participants than had originally been intended (6).

Table 1: Overview of focus groups held

Focus group	Demographic	Department	Number of participants
1	Female, 2nd year	Department 1	3
2	Female, 2nd year	Department 2	5
3	Female, 2nd year	Department 3	5
4	Male, 2nd year	Department 1	2
5	Male, 2nd year	Department 2	5
6	Male, 2nd year	Department 3	7
7	Female, 3rd year	Department 1	3
8	Male, 3rd year	Department 1	4

A purposive sample was sought (i.e. a sample which selected participants according to the projects' goals). The target population was individuals studying for a chemistry doctorate at one of three selected UK Higher Education Institutions, in either their second or third year of study, registered as UK-domiciled students (the differences between the doctoral experiences and career intentions of home versus EU/overseas students was outside the scope of this project). Participants were grouped by 'gender', 'number of years into doctoral study' and 'university department'.

During the course of each focus group, participants were given the opportunity to discuss collectively the doctoral

study experience generally and in what ways it tends to shape career intentions. The group was then asked to come to a consensus as to what factors, drawing on their own individual experiences, will determine whether or not the doctoral study experience of a hypothetical student proves to reinforce their intention to pursue research and/or an academic career further. The duration of each focus group was one hour.

3.4 Telephone Interviews

A total of 47 one-to-one telephone interviews were conducted, 24 with women and 23 with men, half of whom had recently completed their PhD and half of whom were in their third year of doctoral study.

Table 2: Overview of telephone interviews conducted

Sex of Participant	Stage of PhD	Number of Interviews
Female	Completed	12
Male	Completed	11
Female	Third Year	12
Male	Third Year	12
TOTAL		47

The sample was selected randomly from the UK-domiciled respondents to the 2006 doctoral chemistry student survey who had indicated that they would not object to being contacted to participate in further related projects and had volunteered their contact details. Virtually all who were contacted agreed to be interviewed. Third year participants were drawn from those respondents who were in their first year of doctoral study at the time of the 2006 survey and recently completed participants were drawn from those respondents who were in their second year of doctoral study at the time of the 2006 survey. Only 11 male respondents who had been in their second year in 2006 proved to be contactable.

Interviews were semi-structured to flexibly elicit participants' accounts of their experience of the doctoral study. In particular, participants were encouraged to reflect on how their attitude towards their study had varied with time and how their career plans may have consequently changed. The telephone interviews were intended to enrich the focus group data by providing personal stories which, it was anticipated, focus group participants may not have felt able to share in a public forum.

4 Findings

The research identified a number of factors that may discourage a greater proportion of female than male chemistry PhD students from planning to pursue research and/or an academic career on completion of their PhD.

4.1 Deterrents to Pursuing Research

The majority of male and female chemistry PhD students begin a PhD a career in research (some participants, however, reported they had simply drifted into a PhD, having not known which career they wanted to pursue upon completing their first degree), but the 2006 RSC survey showed that many women who begin a PhD with this intention change their minds (72% of first year women but only 37% of third year women intended to pursue a research career). The following scenario, although speculative, might explain this pattern.

A number of factors were identified as deterrents to women pursuing research. These can be grouped into 3 main aspects of doctoral study, i.e. into those which relate to, (a), supervision, (b), research groups and, (c), the research process. It would be reasonable to assume that each deterrent:

i) Would often be unforeseen by the student, only becoming apparent to them once doctoral study had begun, or sometimes the student would have been aware of the deterrent but underestimated its significance;

ii) Would have the greatest impact in the second year which is the stage of doctoral study at which most students reach their lowest ebb when research is no longer a novelty and the end of the study seems a distant sight.

iii) Is sufficient to deter a female PhD student from pursuing research further.

The focus group participants were of the opinion that these factors are pivotal in determining whether a PhD student remains in research upon completing or leaves at the earliest opportunity. Moreover, there was some explicit evidence in the data to this effect (see Data Annex). There was, however, also some evidence to suggest that even where men are affected by one of the factors they generally retain a positive attitude towards research.

An overview of each deterrent will now be provided. More detail on each is included in the Data Annex.

4.1.1 Supervision

The first set of factors concern 'supervision', which refers to the direction and advice provided to a PhD student by the academic supervisor. Students often also have a "second" supervisor but the findings of this report refer to supervision by the principle supervisor.

Participants believed that for a student to have an overall positive experience of doctoral study it is very important that he or she has a positive experience of supervision. The determinant of a positive experience of supervision is that it is 'right' *for a given individual student* in terms of level and scope.

However, while it was frequently acknowledged by both male participants and female participants that often supervisors are difficult to approach to discuss more personal as opposed to science related issues, female participants alone reported being deeply affected by this. Unlike men, women felt it important that their supervisor was aware of their personal circumstances and life events.

Furthermore, while male participants and female participants both said they felt their supervisor lacked interpersonal and management skills, female participants tended to report this was of significance. Unlike men, women felt they would benefit from greater reassurance from their supervisor, but that their supervisor had failed to provide this as a consequence of his/her lack of 'people' skills.

The perception that students are frequently either 'under' or 'over' supervised was widespread. Nevertheless, some female participants, unlike male participants, admitted experiencing these issues in the extreme. For example, some women talked about how, in their cases, these issues had extended to either favouritism or victimisation respectively.

Where male participants had experienced significant supervision problems they had been active in resolving them. By contrast, female participants said they did not feel sufficiently empowered to address supervision issues

believing the departmental community would fail to take their complaints seriously.

4.1.2 Research Group

The second set of factors act at the level of the research group. PhD students usually work within a research group. A research group links PhD students, post-doctoral fellows and established academics working on similar projects. Research groups are led by a group leader (who is usually also the student's principal supervisor) and it is generally the group leader who has secured the research funding. Research groups vary considerably in size. It was seen by focus group participants as very important that a student is a member of a research group and feels content within that research group.

However, some female participants reported they had felt isolated and said this was as a result of being in an inappropriate research group for their research interest or because they were not a member of a research group to speak of at all.[17] This circumstance also meant they did not benefit from the support of post-doctoral researchers, support which was seen as vital by all participants.

Other female participants reported that although they were members of their research group, they did not think of themselves as a fully integrated member. A handful of women said they had been ostracised or bullied because of their gender. Other female participants felt uncomfortable with the culture of their research group, particularly the way it operated in terms of working patterns and time.

4.1.3 Research Process

The third set of factors relate to the experience of research work. Participants were of the opinion that for a student to have a positive experience of doctoral study overall, it is vital that he or she has a positive experience of research work.

Participants were clear that research work is very enjoyable and rewarding. Yet they also spoke of its downsides. Scientific research often entails repeating the same experiment many times. This can be a frustrating and stressful process. The desirable result could take weeks or months to produce as the success rate is often low, but the researcher is necessarily working to a deadline. Serendipity as well as skill and experience reduce the time it takes. Yet even with both on his or her side, the researcher cannot predict how long it will take to get a desirable result. This makes planning difficult. Relying on equipment and machinery that may not always be in service exacerbates these issues. Furthermore, the participants reported that the chemistry PhD programme places emphasis on performing a sufficient number of successful experiments, as opposed to the student learning research techniques.

Both female and male participants expressed that they had not anticipated the reality described above at the start of their PhD (most PhD students will not have undertaken primary research before). However, the data show that women and men respond to the realisation in different ways.

Male participants had come to view the frustration, the stress and the pressure as a rite of passage which will result in their acceptance into the scientific community. This perception enabled them to respond to the challenges inherent in the research process pragmatically and philosophically. By contrast, there was no evidence that female participants shared a sense that the PhD research process is merely 'an initiation'. Instead, female participants were preoccupied with anxiety that a poor success rate in terms of their experiments would reflect badly on them personally.

4.2 Deterrents to Pursuing an Academic Career

Although the factors above were sufficient to put some female participants off research, many were only dissuaded from remaining in academia. Some were put off because academia was the environment in which they experienced the negative factors discussed above. Others were discouraged by factors relating to, (a), the characteristics of an academic career, (b), the impediments female participants believed they could expect to encounter en route to becoming an academic and, (c), the sacrifices female participants believed they would

[17] It may be the case that women are actually less likely than men to be a member of an appropriate research group, for example, because they are more likely to be working in a new application or in an inter-disciplinary area.

need to make in order to succeed in academia.

It might be speculated that point (a) puts many women off academia all together; point (b) dissuades many women who are not put off by the characteristics of an academic career, from having a short-term academic career; and point (c) discourages women who are not put off having an academic career in the short-term, from planning one long-term and also leads many more to think starting out on an academic career would be futile. The factors account for why only a relatively small proportion of women remain in academia after their PhDs.

4.2.1 Characteristics of an Academic Career

Not everyone will find an academic career in chemistry an appealing prospect. Many chemists follow a research career in industry and some chemists undertake doctoral study with the intention of pursuing a career in industry believing that a PhD is necessary to break a glass ceiling.

Academic and industrial careers were seen as having different appeals and drawbacks but there were no significant gender differences in the attitudes of the participants. Participants had the impression that academics tend to have the freedom to follow their research interests, whereas industrialists tend to be more constrained in terms of the type of projects they work on. On the other hand, participants said they thought a major downside to being an academic was the need to directly secure funding. In contrast, industrialists were understood to enjoy better resources.

There were aspects of the academic career that only women saw as drawbacks. Only female participants said they saw what they regarded the 'all-consuming' nature of a career in academia as a repellent. Female participants were alone in thinking a career in academia would mean a solitary existence at work. Female participants had the impression that academics are unnecessarily competitive towards one another and that this is at the expense of what might be fruitful collaboration.

4.2.2 Becoming an Academic

The majority of scientists spend time undertaking post-doctoral research working under short term contracts before they are considered a possible candidate for a lectureship or fellowship. This process is colloquially termed 'post-docing'.

Remuneration is typically fairly modest. There was some disquiet among male and female participants about this. Furthermore, the short term nature of most post-doctoral posts means that it is necessary to relocate, either within the UK or overseas, approximately every two years. Female participants in particular (but not exclusively) said they were reluctant to begin post-docing because of its short-term nature. This was usually because of the location of their partner's work or because they saw post-docing as incompatible with having a family.

Post-docs face fierce competition to secure a permanent post. Participants said they had witnessed the post-docs in their research group come up against this. Competition is very fierce because in academia there are many more PhD students and post-docs than there are permanent lecturer posts. But participants believed the level of competition has increased in recent years due to the closure of chemistry departments and industrial outsourcing, which have, participants believed, released more experienced chemists into the labour market and made it harder for less experienced chemists to get a foothold on the ladder.

Female participants were very concerned about competition levels. Their worries were fuelled by a lack of self-confidence. There was a tendency among female participants to doubt they were good enough to be the successful candidate. Male participants were aware of the competition they would face to win a lectureship, but said they were unperturbed. By contrast, many female participants who were drawn to a career in academia (in spite of the perceived downsides outlined in the previous section) felt the hurdles to getting there were too high for them to clear.

4.2.3 Succeeding as an Academic

The majority of chemistry academics are male. Male participants said this was encouraging and on the whole female participants were indifferent.

Female participants did report being influenced by the realisation that female academics in their department

typically displayed 'masculine' personality traits such as work-based aggression and competitiveness, and were very often childless.

Female participants said that the realisation of what kind of woman succeeds had a profound effect. It led to a belief that in order to succeed in academia, a woman has to sacrifice her femininity and having a family. For most female participants this is a sacrifice they would not be prepared to make. This was a key reason why even those female participants who did intend to undertake a post-doc were not planning a long-term academic career. For many more female participants it seemed pointless to attempt to become an academic, knowing they would not be prepared to do what they believed it takes to be a successful academic.

Several female participants had been warned that they would encounter problems simply on account of their gender if they chose to continue on an academic path (although it was not made explicit to these women what these issues would be).

5 Discussion and Conclusion

5.1 Issues Arising

The research revealed evidence to suggest that female chemists experience doctoral study less positively than male chemists. There was no evidence that men are more satisfied with doctoral study than women but the overall experience for men appears to be more positive because their expectations are lower at the outset.

Where women are not deterred from research altogether, but are put off embarking on an academic career, evidence was found that this may be because, as it becomes apparent to students what establishing such a career entails, women do not like what they see. Previous work had more optimistically suggested that women look beyond academia because they are more conscious of the alternatives than men.

Socialisation processes (especially "early year" nurture) and biological influences arguably mould women and men differently long before either ever step foot in a chemistry laboratory. For example, in our society, many women may be intrinsically less self-assured and self-promoting than men.

However, this research has added support to the contention that science itself has much to answer for in determining scientists' career paths and outcomes. Experiences of the structures, cultures, environment and norms of practice in science can be seen to play a pivotal role. Experiences during doctoral study lead many women to view research careers, especially in academia, in a negative light.

Although the findings cannot be easily generalised due to the qualitative nature of the research, there is no doubt they raise some important issues.

Chemistry PhD Programmes

There is evidence that something about the process of chemistry research puts women off research more than men. Furthermore, a recent survey of molecular bioscience PhD students suggests that the same gender differences in attitude towards research in molecular bioscience are not observed. This implies that there is something in the nature and culture of chemistry which affects women more negatively than men. In an environment where the UK and Europe need a greater number of technically trained people, and when almost 50% of those graduating with first degrees in chemistry in the UK are female, there is a need to look at how the research experiences of women in particular can be improved.

As things stand, men appear to cope better with chemistry research. This works to sustain chemistry as a male domain, and makes it unlikely that the current model of the chemistry PhD programme will be challenged.

Science PhD Programmes

➲ Supervision

There is a need to make sure that gender is not a determining factor of the quality of PhD supervision. There are two ways in which this could be achieved.

(i) Supervisors, particularly those who have no previous management experience, could be provided with specific people skills training. This should sensitise them to the differing needs for support of male and female students. The QAA[18] directs that an awareness of the range of support available and how students can access it is an important part of the supervision process. Also the supervisory role of post-doctoral fellows could be formally acknowledged and training given. Supervisor and post-doc training could be supplemented by a local pastoral care structure to support supervisors and post-docs.

(ii) Where a student experiences significant supervision problems, mechanisms to resolve these could be made more accessible and the student empowered to use them. Where there are personality clashes it is important that these are identified quickly by both the supervisor and the student. If this is the case then it may be the best course of action is for the student to transfer to another supervisor recognising that this will almost certainly mean that this will also entail transferring to a new project.

[18] The Quality Assurance Agency for Higher Education (QAA) Code of Practice, section 1: Postgraduate research programmes, QAA, 2004 (ISBN 1 84482 168 4).

It is important that if particular supervisors seem to experience clashes with students that appropriate support and training is provided to improve students' experiences. At the very least students could be empowered to approach a neutral third party (as in normal anti-harassment policies) perhaps to act as a mediator. At the moment, while most students will have a second supervisor (a policy in part implemented across graduate schools to address this very problem) students with supervisory difficulties may well be reluctant to approach him or her about the problems they are experiencing. The student may lack confidence in the capability and willingness of the second supervisor to help, fearing the second supervisor will be tempted to side with his or her colleague, leaving the reputation of the student tarnished.

➲ Research Groups

The support provided by research groups was identified by participants as important. Consideration should be given to ensuring that students in small groups are in some way linked to larger groups so that they too can experience the support that those larger groups provide. It is also important that where students are working in laboratories away from the main chemistry laboratories, mechanisms are in place to ensure that they have regular contact with other chemists who understand the particular pressures that they may be experiencing. Related to this is the value that PhD students place on post-doctoral support; as students place such high value on the support of more experienced researchers, it is perhaps important that as far as possible PhD students are linked to post-docs, even if they are from different research groups.

Action on these points could be stimulated if the QAA audited universities on PhD student satisfaction and if potential research students were party to the results. Additionally, the Athena Swan Charter (a scheme which recognises excellence in SET employment for women in higher education and research) could assess departments'/ universities' provision at the PhD level.

Chemistry in Academia

Women reported that they would prefer if academic chemistry was more cooperative in nature. It is difficult to imagine how the nature of a subject can change significantly in a short period of time, however, the increasing emphasis on interdisciplinary work, which by its very nature is cooperative, may act as the stimulus for increased collaboration within chemistry which in turn will provide a better environment for women.

Science in Academia

Women are put off academic careers more than men partly because they do not want to work on short term contracts while undertaking post-doctoral research in universities. Early selection of the best scientists for longer term research fellowships, like the Royal Society Fellowships, with clear exit points, would provide a clear path to an academic position. Evidence is that women would be more likely to opt for an academic career if they are clear at the outset of their chances of success.

The evidence is also that female PhD students are more sensitive to issues of work-life balance than men. It is therefore important that science departments take note of work on good practice, and of schemes like Athena SWAN, to improve the working environment. This will in turn provide more positive inducements for women, and some men, to stay in research. It is also important to realise that culture varies from research group to research group and so the implementation of good practice does need to be in all parts of the departments and not just to processes affecting staff directly.

The way in which PhD students see academic female role models will only change in the medium term if more stay in academic careers. Better practice in departments may also affect positively the way female PhD students see female academics.

5.2 Concluding Remarks

Given that science and chemistry have been dominated by men it is perhaps little wonder that many women feel less than entirely at ease with it, and with the similarly male setting of academia.

It is clear from the findings of this study and others that increasing the number of women going into chemistry is not enough to increase the numbers of women at all levels. There needs to be more fundamental culture change in university chemistry departments to produce an environment that is more encouraging to women.

6 Recommendations for Further Research

- Having identified what factors deter female chemistry PhD students from pursuing research further and/or academic careers, the next step should be identify the proportion of female students deterred by each factor (i.e. the relative influence of each factor).
- The same methodology that was employed for this study could be used to find out whether similar (or different) factors discourage PhD students in other disciplines from pursuing research/academic careers. This will further the understanding of what factors contribute to the loss of women at the PhD-CRW transition.
- Further qualitative (perhaps ethnographic) research is required to explore the important cultural differences between the various branches of chemistry and the influence these have on gender equality and diversity.

7 Data Annex

7.1 Supervision

Level of Supervision

Both female and male participants said they felt that their supervisor provided them with either too little or too much supervision.

Where a participant reported they were receiving too little supervision, this was because their supervisor had a very good reputation and consequently had a large group and/or because their supervisor had external interests (such as running a spin-out company).

> *"My supervisor was very high up in his field. There was very little interaction at all. He palmed me off on a post-doc who left, so I ended up not getting any help at all."* (Elizabeth, completed)

> *"My supervisor was a professor who had an awful lot of pressure on him to divide up his time…So his approach was very, very, very hands off. He basically left us to our own designs. If it wasn't for the fact I was very lucky to have three incredibly experienced and helpful post-docs in the group, I really would have packed it in."* (Christopher, completed)

The above quotation from a male participant underlines that the problem of under-supervision is one encountered by both male and female students.

That said male participants were determined not to let this distract them from their goal of an academic career, a determination women did not share.

> *"My supervisor wasn't the most supportive at times. But I've managed to come out of it still positive about the experience. If I do go into academia, I would probably want to be with a different supervisor…I don't want to be put off academia too much simply by my experiences of the wrong supervisor…there was a post-doctorate researcher who was mentoring me throughout the course of my PhD and he was very capable so quite often my day-to-day questions would go to him."* (Rob, completed)

Only female participants reported they were or had been in a situation where they perceived their supervisor was giving other students greater attention. This adds a new dimension to the problem of under-supervision, which it would be reasonable to assume will render it far more affecting.

> *"I've found my PhD extremely difficult. Really, really difficult. Mainly due to a lack of support. It's such a big group and it's really difficult to get hold of my supervisor and then when I do get hold of him, I don't get much help back… There's been some really bad times when I've had no help for about three months…When he gets results from his favourite people, he's 'oh this is really fantastic!'. But with a few of us, me included, he'll - not blank you as such - but it's just really difficult to talk to him…everybody's supposed to have a dedicated post-doc, but mine left. "* (Sian, third year)

Occasionally, presumably only in rare circumstances, students end up without supervision at all. This had happened to two participants, one female and one male. Their accounts are provided below. However, it would not be appropriate to draw any gender related conclusions since each quotation represents only one person.

> *"If I had to sum up my PhD in a word it would be 'hideous'. I worked myself to the point of a nervous breakdown. My supervisor got offered a job somewhere else and left. He still emailed me saying 'I expect these results,' but I wasn't having any input from him. I was not having the best of time with my health and my supervisor had disappeared off! And I had project students I was expected to look after! I was never given another supervisor."*
> (Sara, completed)

> *"My supervisor left about two years ago. I've just been going on by myself. It was a bit stressful at the beginning but I found my way. Now I know what has to be done so I don't really need any supervision. But we do keep in contact. We speak maybe once every two or three months."* (Johnny, third year)

Where a participant reported they are/were receiving 'too much' supervision, this was because their supervisor was genuinely very interested in the student's results and/or due to their supervisor being a young, non-established

academic with little experience of supervisory duties.

Participants who were still relatively new to their studies reported how a high level of supervision was very useful.

> *"My boss is down in the lab at least twice a day, not in an ominous way, he's just taking an interest. I think he remembers more about what we're doing than we do. He always knows what everybody is up to. In some ways that's quite good because it's easy to coast through and say 'I'm not really bothered today,' but if you know that in four hours your boss will be back down and he's going to want to see something that you've done, it helps to keep you on track."* (focus group 5 participant, second year men)

But most described how being under the constant gaze of their supervisor soon added pressure and caused anxiety about developing the skills to be an independent investigator.

> *"One of my supervisors doesn't have much experience of running a group so he spends the whole time breathing down your neck. He always wants to look at your results, literally as you get them and he doesn't give you much space to actually look at your own work and evaluate what you'd done. So it felt very pressured all the time."* (Lisa, third year)

However, while the problem of enjoying too much supervision is one encountered by both male and female students, only female participants reported they were or had been in a situation where it began to feel like victimisation.

> *"My supervisor was very controlling…I was hiding from him at some points because he was coming down to see me twice a day to see what I was doing. It was good to begin with but when you get to know more, it's irritating. He was always trying to push me harder. If the boys didn't achieve something, fine, whereas if I didn't achieve something then that was a problem and I should be working harder."* (Alice, completed)

Again, it would be reasonable to assume this situation will magnify the impact that this supervision problem (over-supervision) is likely to have on affected students.

Participants were happiest if their supervisor was there only if and when they were needed.

> *"My supervisor isn't in the lab all the time but I know he's always there if I've got a problem. That is a massive help because your morale does get quite low sometimes when the work isn't going to plan and you just think 'Oh b******* to it, I'm not doing it any more' and he says 'Okay, let's sit down and discuss it.'"* (Linda, third year)

Scope of Supervision

Most participants remarked they rarely discussed personal, non-science issues with their supervisors. However, while male participants were entirely indifferent to this, typically women would change it if they could.

> *"My supervisor wasn't very understanding of your social life and personal needs. It was always 'you should be working, working, working'. If it wasn't to do with work, he didn't understand. That was the hardest thing."* (Sue, completed)

> *"I feel academics can be a little narrow minded at times. I did have some personal problems not that long ago and I talked to my supervisor about it but he wasn't too sympathetic. That annoyed me a bit. There are more important things than a tiny little area of chemical research!"* (Natasha, third year)

Related to this point, participants were often of the opinion that supervisors were typically 'not great people-people' and that 'the best scientists do not necessarily make the best supervisors'. By that, participants were implying that supervisors sometimes lack interpersonal and management skills.

Female participants saw this as a more significant problem than male participants. For example, focus group 7 participants agreed that women need more encouragement than their male counterparts to excel, but concluded that they are often denied it because supervisors tend to lack 'people' skills.

> *"Our supervisor lacks management skills. And communication is a big problem. I find that difficult."… "I think the problem is supervisors don't really see themselves as managers. And they should."… "The problem is the supervisor is a scientist and he's got to that position on his science skills not on his management skills and suddenly he's asked to lead and support everybody in their group and see the individual as an individual and make sure they've got*

> *what they need.". . . "I had a supervisor in industry who was very positive and very encouraging to me. He spent a lot of time saying, 'You are good at this and you can do it and there's no reason why you can't carry on with chemistry.' Nobody ever told me that before. Everybody in the group is different; the guys maybe don't need to be told that they're good because they have quite big egos anyway. But other people, particularly girls, maybe need to be told a bit more. Realising that is part of being a good manager. (general agreement)"* (focus group 7 participants, third year women)

By contrast, these focus group 8 participants (male) took the view that:

> *"If you're doing a PhD you shouldn't need a good manager. You should be clever enough and self-sufficient enough to get on with it yourself. (general agreement)"* (focus group 8 participant, third year men)

They felt that poor management skills could be cancelled out by reputation.

To summarise the data up to this point, participants' accounts of their supervision experiences revealed that male participants encountered the same supervision problems as their female counterparts, but that female participants were more likely to be severely and deeply affected by these.

Resolving Supervision Problems

Participants agreed that students should address supervision problems head on if at all possible. This was because if a student is suffering a negative supervision experience they are unlikely to be enjoying their doctoral study experience as a whole. Students seeking to stay in research were all too aware they need to be on good terms with their supervisor for the sake of their future careers. Supervisors not only provide a crucial reference but often actively help students find their first research job either by giving them a post-doc position or putting them in touch with a contact, a former student, or supervisor for example. In addition, participants were under the impression that,

> *"When it comes to getting a lectureship, the impression I have is that backroom dealings are very important. It's not just a case of being good and having good ideas. It's who's supporting you."* (Lewis, third year)

Where supervision problems are not resolved they can continue to have considerable consequences, even after the student has officially left the department.

> *"I had fairly big problems with my supervisor. . .The upshot was it took him six months to even sit down and look at my thesis. It caused me a lot of heartache because I got offered post-docs but I had to turn them down. But then I thought, if it's going to be like this, do I really want to stay?"* (Jyoti, completed)

Significantly, where male respondents had experienced significant supervision problems they had apparently responded differently to female participants in the same predicament, approaching a very senior member of staff for help. The second supervisor safeguard was seen as largely impotent by both sexes, apparently because departmental politics get in the way; moreover some participants had never even spoken to their second supervisor.

> *"I've had clashes with my supervisor here and there but that's sorted out now. I resolved it via discussions with the Head of Department."* (Dean, third year)

This male participant had actually managed to change supervisors.

> *"I have changed research group. It's quite a lengthy procedure but it all turned out fine. Initially I was involved in mediation between me and my supervisor but that got a bit heated so then I asked the Head of School to take over and he sorted it all out for me."* (focus group 6 participant, second year men)

Women on the other hand were typically not prepared to draw attention to the supervision problems they experienced, let alone in such a drastic way. There was widespread resignation that it simply was not worth it.

> *"Academics stick together. . .and I definitely don't ever want to be perceived as a raging feminist but at times I think, dare I say it, the men maybe stick together a bit more."* (Jyoti, completed)

This was compounded by a perception that objectionable behaviour on the part of senior academics generally goes unchallenged.

> *"It's well known that the top chemists are really not very nice people and treat their groups horrendously but everyone thinks that's acceptable and that's how you become a successful chemist – to be horrible to your*

subordinates. Nobody ever stands up to them and says, 'Actually you treated me really badly.' You'd just be laughed at…" (Alice, completed)

There was also a perception that only the complaints of male students were taken seriously.

"One of my supervisors was quite…shall we say, blunt. When you've been insulted many times, it gets to you and one of his students actually quit because of it. I just don't think he realised what effect it was having on us. But one day someone went to another supervisor about it – and that was a guy, do you know what I mean i.e. its not just the girls being oversensitive, it's one of the guys – so then things started to change in that group and it became a much better place to work." (Lisa, third year)

Yet the following quote illustrates that even the most serious supervision problems can be successfully resolved with the backing of others in the department, even if the student concerned is female:

"The first twelve months of my PhD were hell. I didn't feel my supervisor was professional. In fact I felt very bullied. It was a very bad situation. When things came to a head, my other supervisor – he was my personal tutor when I did my undergraduate degree – said 'Look, you can either quit or move to a different supervisor.' So I changed supervisor, someone who I'd known for a long time, and he was excellent. He was firm but fair, treated everyone on an equal basis and dealt with you as an individual." (Hannah, completed)

Participants advised that prevention was preferable to cure. If at all possible, PhD students should choose their supervisor very wisely in the first place.

"When I met with my supervisor before I started, I guess when he was interviewing me, I was interviewing him at the same time. I really liked his way of thinking so I knew we'd get on. It was important to me that I had a supervisor I got on with." (Kevin, third year)

Participants added, however, that potential PhD students should also "do their homework" on potential research groups. The research group is the focus of the next section.

7.2 Research Groups

Focus group participants unanimously agreed that experiences at the level of the research group are pivotal in determining whether or not PhD study is a positive experience overall.

Being Without a Group

Participants attached a great deal of importance to being a member of a research group. However, while the majority of chemistry PhD students are members of a research group, a sizeable minority of participants divulged they were not allied to a research group to speak of. This was usually because the participant was working in an area that was not mainstream within the department. Women, unlike men, were concerned by their non-affiliated status.

"Whereas other people have a permanent post-doc or are one of five or six PhD students working towards the same goal, there's just me. Nobody works with the type of chemistry I work with within the department…And the building I'm in is also separate from the main chemistry building so that's also a bit strange…I wasn't aware it would be like this because when I applied, I applied for a different PhD." (Sian, third year)

An obvious implication for a student who is not a member of a research group is the acute isolation the student is bound to experience on a daily basis.

"It was only me working on my project. There weren't any post-docs. So I felt like an island: very isolated." (Kate, completed)

The Importance of Post-doc Colleagues

A further implication for a student who is not a member of a research group, and one which is alluded to in the quotations above, is that he or she will lack the support of post-doctoral fellows. It was not uncommon for a participant to say they felt indebted to the post-docs in their group. They were keen to stress how post-docs are a vital source of practical help and day-to-day advice especially in the initial stages of the PhD, providing an extra, very welcome level of supervision.

> *"Post-docs are very helpful for the lab side of things. Supervisors often become a bit detached from all that and forget the constraints that you have. When you go and speak to the post-docs they give you a different kind of supervision that's more helpful."* (Lucy, completed)

Post-docs were also said to act as PhD student's main role models.

> *"They've been where you are and they've got the right balance in how to do things…they're good fun but they are really devoted to their work and get stuff done. It's a bit like a family…they're the older brother or sister. You think if you get to that level you'd like to be looking out for the first years when they come in and to be able to pass on all the good things that you've learned from them."* (focus group 1 participant, second year women)

They can, however, on occasion be hard task-masters.

> *"I had a massive argument with my post-doc person once because I wanted to leave at 4 and he wanted me to stay until 6. He had a nasty 'go' at me saying I'm not dedicated to my project."* (focus group 2 participant, second year women)

Belonging IN the Group

Where a student is a member of a research group, participants agreed that it is very important that he or she feels they belong in that research group. In other words, for the overall doctoral experience to be positive, a student needs to be surrounded by others undertaking broadly similar work.

Most participants believed they were in an appropriate group. However, a handful of participants – female participants – felt they were in the "wrong" group, usually on account of undertaking interdisciplinary work. The most striking example of this was revealed in one of the female focus groups (focus group 7). Two participants, working entirely independently from each other, explained how they are erroneously working within biochemistry groups because their projects involved a degree of biochemistry at the very outset. Having had to remain in biochemistry groups throughout their doctoral study had profoundly affected their doctoral study experience. Both women had felt disorientated and had considered not completing their PhDs as a consequence.

> *"I hate biochemistry but I'm still stuck there"… "Me too. I've even ended up working in a different building to the one I thought I'd be working in. Everyone's a biochemist. Nothing's right. It is a struggle"… "Yeah, I've had enough now. I just want to get it over and done with as soon as possible now."… "I have to constantly remind myself 'it's only until October, then you can leave'. Because if was any longer than that…"… "I don't think I want to do any form of research after my PhD."* (focus group 7 participants, third year women)

The impact of being in the "wrong" group should not be underestimated. It certainly has the potential to deter students (but perhaps only female students) from continuing in research.

> *"Although I had a group, we weren't working on the same project. So basically I was working by myself and I found I was quite isolated. So far I've applied for a post-doc and a job in commerce but I don't know which one to go for. The post-doc is interesting, but would I be able to interact with more people than I did during my PhD? That's why I've been looking at commerce because it involves talking to more people such as meeting customers. "* (Rebecca, completed)

Belonging TO the Group

In addition to feeling he or she belongs in their research group, participants believed that a student also needs to feel they belong to a research group. By that, participants meant that a student needs to feel integrated for doctoral study to be experienced positively.

Ideally the student should feel their research group is "like a big family…everybody in the same boat." (Dominic, completed)

Most participants felt they were part of their research group. However, a sizeable minority of female participants talked about feeling on the margins.

Sometimes very practical reasons underlie this.

> *"I've switched groups throughout my time because my research focus has shifted. So I've been with different people at different times and I've had to re-establish a group of chums. I've never really been part of any one of the groups*

I've been in." (Lisa, third year)

Sometimes the underlying cause, for example feeling intimidated by the rest of the group, eases with time.

> *"I do feel like I fit in now but I was very unsure of myself to begin with. I don't know whether it's a female thing or what. My group are very mouthy and confident about how wonderful they are. It was a bit intimidating to start with. But you get used to them."* (Megan, third year)

Sometimes the situation is far more troubling. This participant explains how she has been ostracised by the other members of her research group on account of her gender.

> *"The other guys don't really talk to me. Because they were all boys I think. It's some blokey thing. They just ignore me all the time. They're alright really. But I just keep myself to myself most of the time."* (Lucy, third year)

Another woman recalls her experience as a victim of bullying. She said she had developed a serious mental health condition while studying for her PhD and had to have counselling. She attributed this condition to her doctoral study experience, which she said was so negative as a result of being in the minority as a woman.

> *"I was in a very male-dominated group…I was being picked on constantly by other members of my group. It was just the kind of things which don't seem very much but when it's every day it begins to drive you crazy. …I think the reason a lot of people get out of chemistry after a PhD is just because the PhD environment isn't always a happy one. You're just supposed to grin and bear it and hope that it gets better."* (Alice, completed)

Feeling Comfortable with the Culture

Lastly, the focus groups identified that for a student to have a positive experience of doctoral study, he or she needs to feel comfortable in their research group. This is only possible if he or she feels at ease with its culture and work dynamics, which purportedly vary widely from one research group to another (apparently determined by the section culture, leading academics in the field, and the personality of the supervisor). Most participants were happy with their research groups in this respect.

For example, in focus group 4 two men in their second year, from different research groups recounted very different daily experiences relating to the culture of their research group. Essentially one group apparently behaved as though students, the other apparently as though employees. Nevertheless, both men were happy with the way their group interacted.

Of those participants who were not comfortable with the culture of their research group, most were organic chemists and female. Organic synthetic chemistry is seen as having a particularly 'macho' culture.

> *"I hated the stress caused by the competitive nature of the environment we were working in. You would go in and somebody would say, 'Oh what time did you leave last night? I left at half past eight'. That's a typical environment for synthesis PhD students to be working in."* (Charlotte, completed)

That is not to say, however, that all women in organic chemistry are disturbed by the culture of their research group.

> *"Organic chemists are expected to work at a lot longer hours in the lab for their PhDs, than say inorganic or physical chemists. You're typically working from 8.30am to 7.30pm…And you have to work weekends. But I didn't mind. I really enjoyed it."* (Jyoti, completed)

The following participant was unhappy with the expectation that students should be seen in the laboratory.

> *"I thought I might have a little more time to spend on the less practical side – on the theory, but it was very much the practical side that seemed to be more important…you do need to do a lot of research and get a lot of results so… but I think it was sort of frowned upon if during the day you did any theory work; that was what you did in the evenings. As much as I understand why, perhaps there should have been a bit more freedom to… it shouldn't have been frowned upon to be in the library."* (Lucy, completed)

Male participants, on the other hand, seemed to have had a realistic impression with regards to the hours the PhD would demand.

> *"I had friends who'd already done a PhD. They said to me, 'You should know, it's very hard work'. I personally get to the lab at about 7am and come out at 5pm most nights. That doesn't leave much time for friends and family, bar the*

weekend, but I knew it was going to be like that. That's what I wanted to do, and that's it. It's just a case of working hard to get the results." (Toby, third year)

Choosing the 'Right' Group

Participants were adamant that anyone considering doing a chemistry PhD must choose their research group wisely. It was said that potential PhD students should make every effort to ensure they will be allied to a research group (with post-doctoral members) and that that research group will be an appropriate group for them, comprising people they can establish a rapport with and who work to a rhythm they will be happy to join.

> *"Before I signed up to do a PhD someone in research a few years older than me had said to me, 'it's not about what you're doing at the end of the day, it's about who you're doing it with'. If you've got rapport with your supervisor and your group, on the days when things aren't working, you need to have people around who help you through that (general agreement)."* (focus group 5 participant, second year men)

7.3 Process of Research

The third set of factors found that may act to deter a much greater proportion of female than male students from planning to pursue research upon completion of their PhDs relate to reactions to the process of researching, including the often poor experimental success rate chemists must tolerate.

The Reality of Research Work

Both female and male participants reported they had been shocked at how frustrating, stressful and pressured research can be.

> *"Everyone warned me it was going to be difficult. That you go through a rollercoaster of emotions and that kind of thing. But I wasn't prepared for how extreme it was going to be and how frustrating it was going to be."* (Caroline, third year)

> *"PhD study was a real rollercoaster. It's been a series of really high highs and really quite low lows. I'm quite confident I will never experience quite as much of a low again."* (Christopher, completed)

> *"Research completely consumes your life. Your life is just your PhD. You're working all the time towards it. It's hard and it's stressful…."* (focus group 6 participant, second year men)

However, the data infer that women and men respond to this realisation in different ways. The focus group 6 participant went on,

> *"…Yeah, the PhD causes a lot of different emotions. Happiness, sadness, stress. You get through a lot of emotions in three years. But it's a good life. It's a good way to learn life to be honest."* (focus group 6 participant, second year men)

Male Participants' Responses

Male participants were pragmatic and philosophical.

> *"The nature of research is such that you're always going to go through periods of famine. You just have to persevere."* (Mick, third year)

> *"Research is research so some things aren't going to work out. That's when you have to put the extra time and effort in."* (Dominic, completed)

> *"You want to make progress, sure. But I don't really mind if it's a 'no, that doesn't work'. It's still progress. When you do get a result, you know it's an achievement."* (focus group 5 participant, second year male)

Male participants also displayed resilience.

> *"When you're not getting any answers, it's like you're knocking your head against a brick wall. But I'm someone that can put that behind them. If I do have a bad day, I just look at things again tomorrow and move on from there."* (Dave, third year)

> *"It does get you down if things don't work, but you chose to do it. And you settle in and settle down, you build up a*

rhythm and everything seems to be alright after that. You just keep going really." (Amir, completed)

"I had all this information and I wasn't able to figure out exactly what was going on. But it was just a matter of time. But I got through it and figured it out and I was able to write a publication. I think it was just part of the process really." (Steve, completed)

Most male participants described how they felt a sense of inevitability that they would ultimately get through the harder times.

"There are points at which you want to pick your machines up and chuck them out of the window and everyone gets that. But I was designed for this, this is great." (focus group 4 participant, second year men)

"I worked for the first nine months and I didn't get any results. But there didn't seem to be that much pressure on me because it was assumed that eventually I would get something. And when you get something you can set up the system and then tweak things and then generate lots more results and fast." (focus group 5 participant, second year men)

"There were days that turned into two or three days sometimes where you're just fed up with it, but there's never been a point at which I've thought to myself, 'I can't do this anymore'." (Kevin, third year)

These attitudes may well have roots in macho bravado. However, the data also revealed that they may be linked to an apparent tendency among male chemists to rationalise the downsides of PhD research as being part of "an initiation" which leads to being accepted as a fully-fledged scientist.

"I don't think actually a PhD is anything like – or at least I hope that it's nothing like –having a career in research. So if you like the PhD you'll probably quite like the rest of it. I think it's kind of a trial of fire…" (focus group 4 participant, second year men)

Accordingly, a proportion of male participants understood the hardest aspects of doctoral study as a mechanism by which those who were up to the job could be selected.

"I knew a lot of friends training to be medics and they were worked to dropping point. That's apparently the done thing. It's to sort the wheat from the chaff. I really felt that's what my experience of a chemistry PhD was. They push you to a certain point to see if you can hack it." (Anthony, completed)

"Doctoral study is certainly the decider. About halfway through you know whether you're in or you're out. There's no middle ground there. It's not for everybody but by the end of it you do know whether you want to do this anymore." (focus group 4 participant, second year men)

Female Participants' Responses

Female participants, on the other hand, found it harder to accept some of the realities of research work.

"I've found out that research happens at a lot slower pace than I imagined (general agreement)"… "When you start you have ideas of the amazing things you'll achieve. But then you only achieve 40% of what you set out to do. That's hard"… "Yes, it is very frustrating." (focus group 1 participants, second year women)

"It's hard because in chemistry it's not how hard you work that determines how your PhD comes out, it's luck. I find that really difficult to deal with. Especially because you've got to be quite selfless about it and be happy for other people and just realise that's the way it goes. That's what's put me off chemistry in particular. I can't stand it just being luck."… "It's the same for men. The person next to me gets all the luck and I could actually kill her by the end of most days." (focus group 3 participants, second year women)

Women were far less blasé than their male counterparts about the trying times research involves.

"So far my PhD's been tough. I didn't really get any results until a couple of months ago. I wondered whether there was any point carrying on when nothing seemed to be working and I was going round in circles not being able to see the wood for the trees anymore. You think you've tried everything and nothing seems to make a difference. At the lowest point I was ending up in tears every day. I wanted to give up a lot, but I kept going." (Carrie, third year)

"I'm sick of my PhD because my experiments aren't working…My Mum keeps telling me 'You've only got 18 months. It's not that much longer.' So I'm pushing through and I'm hoping I'll get through things"… "When you feel that

nothing works you just go home and you're depressed and there's nothing you can do about it. You go in the next day and it still doesn't work and then after about a couple of weeks when nothing's worked you just start thinking 'what's the point even bothering anymore'." (focus group 2 participants, second year women)

Although determined not to give up their doctoral studies, female participants said they had found it much more of a struggle to keep going than did male participants. The support of others, especially their supervisor, was purportedly vital.

"I almost quit. I realised I was a year in but I still had no results. My supervisors spoke to me and we looked at my project and looked at where things were going wrong and they were brilliant. I would have left. I said 'I'm quite prepared to leave, I'm not up for this, it's all gone wrong, I can't do anything'. I suppose for a few months afterwards I still thought, 'Have I made the right decision?' But if it wasn't for my supervisors I'd have left after my first year." (Annie, third year)

Female participants believed that part of what had made it so hard to continue was their anxiety they were personally responsible for the difficulties they were having.

"I have a knack of burning water! I just can't do synthetic chemistry very well…" (Annie, third year)

More importantly, they were anxious that others, for example their supervisor, would come to the same conclusion. It might be speculated that women feel like this because they are in a male-dominated environment where women are held to have much more to prove than men to be accepted as a scientist.

"It can be very frustrating if you're going into a supervisor meeting and you've got to tell your supervisor that two weeks work has given completely negative results. Sometimes you do sort of doubt your own ability and think 'Well, maybe it might have worked if I'd have done this." (Natasha, third year)

In some cases, it may have been the supervisor who created the impression that the student should doubt her own competence in the first place.

"My supervisor really dragged my confidence down. I came to the PhD full of enthusiasm and confidence but he made me feel like I'm absolutely rubbish. I put it down to how well the chemistry was going…if my chemistry was going well, I was doing well, if my chemistry wasn't going so well, then the impression I got from my supervisor was that I wasn't doing very well." (Erin, completed)

Men, on the other hand, were inclined not to blame themselves.

"I've spent a year and a half trying to make one thing and I've made it twice and that's not enough. You try, it fails, you try, it fails. You get fed up with it. But more than that you get angry at the people who wrote the paper that doesn't actually do what it says." (focus group 6 participant, second year men)

Whatever the cause of their anxiety, several women said the realities of research work were the reason they did not intend to pursue research further.

"A lot of what's making me not want to continue with research is the fact that you may not get any results. You can go for a full 18 months without getting a good result and it's like you're banging you head against a brick wall. And if you can't see any way out of it, you just keep producing negative results and then the less work you do and the more negative the experience is and the less motivated you are because you're not doing very much and everything that you do is not working and then your boss isn't happy with you because you're not doing much work." (focus group 7 participant, third year women)

"I won't be staying in research having had the experience I had in my second year…a real lack of motivation and a feeling of dread that nothing's going to work…feeling like you're flogging a dead horse. I don't think I can continually go through that. No, I don't think I could do that again." (Mia, third year)

Among female participants there was no sense that the PhD is an initiation, i.e. that it was intended to be difficult.

"I found working for my PhD very stressful and very pressurised. It was the upper limit of what I can handle – if not slightly beyond it. And I didn't want that kind of stress for the rest of my life. A certain level of stress you need to feel, yes. But there's a point at which is becomes detrimental to you." (Hannah, completed)

In summary, the response of female participants to the realities of research work stood in contrast to that of male participants. Whereas most male participants saw doctoral study as a test they were sure to pass, thus permitting them to enter a scientific profession, a significant proportion of female participants saw doctoral study as an ordeal they needed to endure until they could make their excuses and leave with their dignity intact.

7.4 Characteristics of an Academic Career

General Perceptions

Both male and female participants believe that the main advantage of an academic career was intellectual freedom and creativity compared with corresponding constraints in industry.

> *"In academia you are able to put your own input into your research rather than having someone tell you 'the company needs you to make this chemical!'"* (Lucy, completed)

> *"Academics have a lot more freedom than industrialists. If you spot something that you think is interesting then you can go and explore it, whereas in industry it would have to be very relevant to what you were doing.". . . "In academia you can go and explore whereas in industry, if you're not meeting the target you're supposed to be meeting, if you do that it's 'What are you doing?!'"* (focus group 8 participant, third year men)

However, participants were divided over this as a virtue. Some were not attracted to doing research for the sake of it. For those participants, industrial research was preferable on account of its applied nature.

> *"You get to see tangible results far more quickly. And when products hit the shelves, you can say 'I was involved in developing that'. My family, who aren't scientists, can understand what I do."* (Phoebe, completed)

> *"The advantage of working in industry is that your results get put into a product. I don't particularly like doing blue skies research where I'm working on a thing that will never get used. I want my work to be useful and if it's got no use to society then I don't really see the point working on it."* (focus group 3 participant, second year women)

> *"In [the pharmaceutical] industry, you can actually make drugs, drugs that make it onto the market and have a therapeutic use. In academia, research is sometimes done just to figure stuff out and not actually to produce anything. Actually one of the things I'm working on now should make it to the market relatively soon."* (Mark, completed)

> *"The primary difference between industry and academia is that in industry they 'solve' problems whereas here we 'investigate' problems. You can go on and on for pages and say nothing. I can't stand it."* (focus group 4, second year men)

Chemistry in academia was seen to involve greater variety, in an environment where the chemist could have greater control over their day.

> *"Industry is very restrictive compared with academia, in terms of how you work on a day-to-day basis."* (Kate, completed)

> *"Having had a taste of industry I've realised chemistry in industry isn't the kind of chemistry I want to pursue. Basically people were going to work and doing exactly the same reaction every single day and there seemed to be very little variety in their work and routine. I want more diversity in the work I do. . . in my post-doc role I structure my day as I see fit and you do what you have to do to achieve your goals for the day so it is very much a flexible working environment. If I'm not in at nine o'clock on the dot, that's not a problem."* (Dominic, completed)

Both male and female participants referred to the requirement to continuously source funding and deal with paperwork as a disadvantage of working in academia.

> *"It's all about applying for funding. My supervisor doesn't actually seem to do any research. I was always told academia's good because you can do the work that you want to do. But you don't really. You just end up getting stressed. It's not hands on enough for me. I like to be involved. A post-doc would be OK but being an academic seems to be like having a desk job and dealing with paperwork all day."* (focus group 4 participant, second year men)

> *"My impression of being an academic is that you spend most of your time begging for money off research councils."* (Caroline, third year)

The political side of academia also acted as an irritant.

> *"When I started my PhD I was torn between academia and industry. Now I'm totally, totally off academia. It's all the bureaucracy and politics."* (focus group 3 participant, second year women)

> *"It sometimes feels it's not down to how able you are but to who you know."…"When you go to a conference you can see that academics are always trying to butter people up. It can be a bit sick, that it's not just about the science."… "And there seems to be pettiness that wouldn't be allowed in any other business but they get away with it in this environment because there's no rules about it. In an industrial application you'd never get away with it." … "Also when you go to conferences you see some of the big name academics and they're the most arrogant b******* you're ever likely to meet. Their behaviour is sometimes really quite bad. And I don't like that side of it, the arrogant side. But I think I can stay in the system and not sell my soul to the devil."* (focus group 6 participants, second year men)

Both female and male participants felt industry was usually better resourced.

> *"I've just come back from three months in industry and I got ten times as much work done as I would have done here because things don't break. Everything works."* (focus group 7 participant, third year women)

> *"In industry everything works well because it has to work well. Whereas here, nothing goes to plan at any stage (general agreement)."* (focus group 8 participant, third year men)

Ultimately both sexes agreed that staying in academia is a labour of love rather than necessarily a sound career move. The sexes parted company in that it was mainly female participants who identified the disadvantages to academia as being that it is an all-consuming, solitary career, involving too much competition at the expense of collaboration.

Academia as All-consuming

Female participants viewed an academic career as a "24/7" career.

> *"There's so much pressure in academia. You've got to do research but you've also got to get funding and do a lot of teaching as well. You have to spread yourself far too thinly. Whereas in industry you've got more of a support network. You don't have to teach anyone what to do or try and raise the funding required to run projects. You can just focus on the research and development."* (Phoebe, completed)

The demanding role of the academic was seen to leave little time for other interests or relaxation.

> *"It would be nice to go home at the end of the day and not have to think about work until the next day."* (focus group 2 participant, second year women)

> *[What impression have you formed so far about what it would be like to be an academic?] "Not a good one"… "My supervisor just works all the time, from 8-7"… "Same as ours"… "It seems to be their lives. I say 'I need to go out with my husband' or whatever and they say 'What? But you need to do this reaction.' Well, surprisingly, no, I don't have to do this reaction. I do actually have a life outside chemistry. And they don't seem to understand that because, especially my supervisor, their career is their life."* (focus group 3, second year women)

For some this was a basis upon which to rule an academic career out.

> *"You have to give up your life to be a scientist. And that's not actually what I want anymore. At one point I would've been quite happy to do it. But actually having lived it I don't actually want that lifestyle anymore. I don't want to have to put in endless hours just to keep a job."* (Lisa, third year)

> *"I'm not enjoying chemistry as much as I used to and I think to be an academic you have to really enjoy it and you have to want to think about it in your own time and to a certain extent almost make it your life."* (focus group 2 participant, second year women)

Academia as Solitary and Competitive

Female participants had a sense that academics exist independently from each other.

> *"Nobody seems to get on, nobody seems to talk to each other. There's no social side to any of the staff"… "In the organic section, I don't think they talk to each other if they can avoid it…"It puts you off being an academic. It just looks like such a solitary and unsociable job."* (focus group 3 participants, second year women)

This was seen to contrast with industry.

> *"When I worked in industry it was quite a big company and there was a really nice, sociable atmosphere and the people there were all lovely to work with. This seems a big contrast with academia."* (focus group 3 participant, second year women)

Female participants also had a sense that academics are too competitive with each other, at the expense of collaboration. Women in focus group 3 expressed how, at the beginning of their doctoral studies, they had been incredulous to discover that research groups hide equipment from each other, rather than make it available to all. They saw this as "sad, because it's wasting a lot of science time".

This female participant inferred how, in her experience, it is the excessive competition between research groups that underpins the bullying behaviour of some academics.

> *"There was a professor, not my supervisor, who's a really, really horrible man. He's just nasty and mean to his students. And when you're sharing a lab you all need to get along and share out the equipment so we'd built up an equipment booking system…but he'd go round telling his students 'You need to do this now. I don't care if someone else has booked that equipment, you're using it' and then he'd just throw other people's work away…he'd just switch off the machine in the middle of a process so that his student could use it. I didn't think we should work like that so one day we had this argument…I was maybe a little outspoken…it resulted in the two of us on our own in a stairwell with him bent over me shouting in my face for ages. I never spoke to him again after that. He's had students leave but some people can just ignore him and be like 'that's just what's he's like'…He is not someone I wish to ever work with again and one of the reasons why I want out of academia."* (Sara, completed)

Some areas of chemistry were seen to be more collaborative than others.

> *"Synthetic chemistry is very competitive in the academic community which tends to put women off. Women maybe go towards biological chemistry instead."* (Alice, completed)

But on the whole female participants regarded industry to be a less competitive and more team-orientated environment.

> *"When things start going wrong and you're not getting results you think, 'if only we had a proper team, we could work out how to proceed'. In academia they tend to leave you to bang your head against a brick wall for months and months. I know there's a better way because I've seen it in industry – they put everyone's heads together and sort it out. I think 'do I really want to carry on in this environment when it seems so inefficient?'"* (focus group 7 participant, third year women)

> *"Industry doesn't seem as competitive as academia"…"Yeah, I admit there are pressures but when I worked there, because I was at a lower level, I wasn't really conscious of them. So it didn't seem as stressful as academia."* (focus group 3 participant, second year women)

In contrast, male participants tended to refer to academia as less tense than industry.

> *"I think academia would be a protected environment to work in. There's a kind of laid back attitude towards things which I would enjoy."* (focus group 6 participant, second year men)

> *"There is pressure to get funding but you don't really have stress other than that. It's less stress in general."* (focus group 6 participant, second year men)

7.5 Becoming an Academic

'Post-docing'

The nature of 'post-docing' was found to be the factor discouraging female participants from pursuing academia in the short term more than anything else. That is not to say that male participants were enamoured with the system of post-docing either.

> *"The thing that puts me off academia a little bit is post-docing. After what for me will be nine years of training, I will get 22 grand to go and do someone else's experiments! If you go into industry you're not going to start at the top by any means but you're not going to be somebody else's lab tech either. No, I don't like the post-doc thing. It's like*

paying your dues before you're allowed to do anything exciting. But if you've just spent four years doing that, I don't understand why you have to do it again." (focus group 4 participant, second year men)

"Until you're established in academia, i.e. for the first 10 or 15 years of your career, everything's very short term. I recently got married and we bought a house – incidentally we had to do that on my wife's salary – so I can't move around too much now. We decided I wouldn't post-doc. It would be too disruptive. " (Jeremy, completed)

Some male participants had recently married or had long-standing partners and were beginning to think about starting a family. These men felt it would be difficult in the circumstances to apply for post-doc positions, wishing instead to have a more stable income and permanent base. This would explain one particular finding of the 2006 survey which was that the proportion of men planning to stay in research in academia dropped from 53% in the second year to 36% in the third year.

"I have a young family so I'm looking for a permanent position as soon as I can and whatever that is, as long as it's within science, that's where I'll go. I can't afford to be too rigid." (Steve, completed)

Not all male participants disliked the temporary nature of post-doctoral positions. Men without family responsibilities saw this as an advantage rather than a disadvantage.

"With post-docing you're out of a job one month and in another one a next. But that's never put me off. You get to move around and you get a lot of variety. It keeps things interesting." (Amir, completed)

"I'm not keen on the fact that as a science based academic you're very much tied to one location for an extended period of time. It's not the kind of career you can move around with." (Pete, completed)

When Pete was interviewed he was packing, having agreed to take up a year-long post-doc abroad. Neither male nor female participants were impressed by the typical salary a post-doc receives.

"This may sound shallow, but it's a lot of work for not very much money (general agreement)." (focus group 1 participant, second year women)

"The pay is just so much lower than in other disciplines"… "I'm quite greedy. I want more money." (focus group 4 participants, second year men)

As already noted, female participants in particular seemed to be deterred from academia by the prospect of post-docing.

"I wouldn't mind being an academic. I wouldn't mind the lecturing, or giving my group ideas and then them doing the lab work. But you have to do a post-doc before you can get an academic post and I don't think I could go through that (general agreement)" (focus group 2 participants, second year women)

Like male participants, female participants also found the prospect of post-docing unappealing because of the lack of security provided by temporary contracts and by the relocation aspect. This was a problem for more women than men because women tended to be the ones constrained by where their partner lived because his job was more likely to be taking priority because his salary was higher.

"I'm quite happy with doing post-doctoral work now but the negatives are the temporary nature of the contracts and the fact that I know in two years I'm going to be looking for another job. That's what the appeal of non-academic jobs is, that you tend to have more job security. And you've got to be willing to move to the work. I suppose that applies to other jobs but if you're moving to a permanent position, it's different." (Kate, completed)

"I need to stay in this area when I finish. My boyfriend's a doctor and works here." (Megan, third year)

However, unlike male participants, female participants were also fairly worried about what their job prospects would be at the end of the post-docing process and were concerned post-docing would disqualify them from an industrial career later on.

"I don't want to end up on the track where you're just post-docing for years and never get any further." (Phoebe, completed)

"I've seen and heard on the grapevine that if you start post-docing you sometimes get stuck and you don't necessarily get out of it." (Linda, third year)

In addition to this post-docing was seen as wholly incompatible with a desire to start a family.

> *"The reason research is seen as incompatible with having a family is because you won't get a contract until you're 35 and then it's too late to start a family – well, it's not too late, but it's getting difficult"… "Yeah, that does worry me because I don't want to have kids too much later than 30. But you haven't got much time at all to get settled."* (focus group 3 participant, second year women)

Female participants saw post-docing as the only aspect of the academic career that is truly incompatible with having a family.

> *"If you get a permanent academic position, a lectureship, the flexibility of the work probably makes that quite amenable to having children. It's when you're on temporary contracts that…well I don't think I'd go down the route of having children while I was on that kind of contract. Not from a security point of view."* (Kate, completed)

Securing a Permanent Post

Female participants were much more deterred from pursuing an academic career than male participants by the high level of competition for academic jobs. For example in focus group 2, four out of five participants said they regretted doing a PhD because it seemed to them to be difficult to get a chemistry job, as well as because of their experiences during doctoral study.

Underlying female participants' fears was a tendency to doubt they had a chance of being successful were they to apply for a lectureship.

> *"I started thinking about academia but I'm just nowhere near good enough…the competitiveness for a lectureship is just daft and I think I would just be wasting my time. I mean I would love to do it but at the same time I think you need certain qualities that I just don't have. I've seen a lot of people here who I can imagine being academics and I compare myself to them with regards to creativity of thinking and I'm just not very strong on it."…"When I started I thought I'd end up working for a pharmaceutical company. I'd still like to do that but I don't know whether that will be possible now. I never considered academia for the same reason. I just never thought I'd be able to do it."* (focus group 3 participants, second year women)

> *"My Facebook space has said many times, 'Linda is simply not clever enough!'"* (Linda, third year)

Women saw their male colleagues as being in with a much better chance of securing a permanent post than they were.

> *"There's obviously a lot of good guys around and you think, 'I'd never make it compared to them.'"… "Men are quite often a bit more big-headed. They think they're great. But women are more realistic and think 'no, I'm not that good.'"* (focus group 1 participant, second year women)

> *"There's a lot of people here I can imagine being academics. I compare myself to them and I think 'I'm really not strong on x and y.'"* (focus group 3 participant, second year women)

Whatever the cause of this perception, the effect was that numerous female participants had decided they would not apply for an academic job. As one woman put it, she was "terrified of failure".

It might be speculated that women simply cannot see themselves as academics. It is difficult to know exactly why this may be. Perhaps women are not entirely sure that they possess the qualities, or the personality, required to make it as an academic.

> *"It had crossed my mind to be an academic because I do like being in the university and stuff. But at the end of the day, I don't think I've got the right personality, or whatever, to be a lecturer."* (Megan, third year)

7.6 Succeeding as an Academic

Sacrificing Femininity

Although unperturbed by a lack of female role models per se, female participants were worried by a lack of "feminine" role models (especially, but not only, at the highest level). This implied to them that it is very hard to be feminine and progress in academia.

> *"You look at lecturers in chemistry and out of about 30 people, there's two women. From statistics you think, 'It's going be quite hard to be one of those two women'. Plus the women who do succeed are very strong minded, really strong women that have to fight their whole way up and I don't know if I could do that."* (Sue, completed)

Female academics were described by female participants as extremely ambitious, competitive and aggressive. It was the understanding of female participants that these women have had to be this way, in order to achieve a senior position in a 'testosterone-fuelled' environment.

The upshot of this is that young female chemists *"think you've got to be like that in order to get where they are."* (focus group 1 participant, second year women)

To this end, female participants spoke of making a conscious effort not to behave 'too girly'. But for other women, understandably, this was too much to ask.

Sacrificing Motherhood

Female participants were also perturbed by a lack of female role models who juggle family life and an academic career as this seemed to imply that it is very difficult to do this.

> *"I've been put off seeing how you have to sacrifice having a family. Why would you do that for a job…(general agreement)?"* (focus group 3 participant, second year women)

Female participants said that female staff in academic chemistry tend to be "career women" rather than "super women".

> *"My supervisor was out for most of the year last year because she was on maternity leave…but eventually her husband decided to stay at home to look after the baby. She's put her career first."* (focus group 1 participant, second year women)

Participants believed that the argument that an academic career is incompatible with having a family is sometimes misconstrued. In essence, participants believed that the extent to which this is the case depends on one's priorities. Industry was seen as "more forgiving" of someone who has caring responsibilities but is nevertheless intent on climbing the career ladder.

> *"In industry, having to fit a family in with work is taken into account. But in academia, how much funding you get is just judged on your number of papers."… "Yeah and you get more benefits in industry."… "And you can do research part-time and you can't really do research part-time as an academic."… "I do eventually want children and you just can't have a job in academia at the same time. Plus in industry you will be better looked after, compared to not looked after at all in academia."* (focus group 3 participants, second year women)

> *"Many people in academe have told me it's difficult to come back if you leave and have kids. I think it is possible but the general sentiment is that it's very difficult to do. I know someone who had done a PhD and then left to do administration because it was easier as she wanted to start a family."* (Rebecca, completed)

Female participants said their image of academic chemistry as "anti-family" did not hail from male academics. Rather it was female academics, perhaps less worried about being labelled sexist, who had rendered "motherhood" a dirty word.

> *"My supervisor doesn't understand why anybody would want children, why anybody would even contemplate doing anything except researching. She'll come out with snide comments like 'You're not pregnant are you?'"… "I had a friend who got pregnant during her PhD and the female supervisor just said, 'well that's the end of your PhD, see you later, you can come back in six months time but the chances of getting the productivity we should out of you are probably quite slim so…"* (focus group 3 participant, second year women)

Gender Forewarnings

Disturbingly, a few female participants had been told it is harder for women to progress than men.

> *"When I've asked people for a reference and I've said 'I want to be an academic like you', a lot of them have made the comment that there are very, very few female chemistry academics, particularly in organic chemistry which is the field I'm in, and they've said 'You are going to find it incredibly difficult'…all the academics that have offered me careers advice have said 'Are you sure you want to do that?'"* (Jyoti, completed)

8. Data Synopsis

The table below provides the reader with a quantitative overview of the qualitative data. This is intended merely to contextualise the findings. The numbers cannot be generalised to any extent. That said, the two areas circled highlight that two patterns can be found even among a very small sample: (i) the tendency for men to experience of doctoral study positively on the whole and (ii) the tendency for only a small minority of women PhD students to post-doc.

Sex	Doctoral Study Stage (n)	Doctoral Study Experience			First Destination (intention/actual)				
		Good	Mixed	Poor	Post-doc	Research outside academia	Chemistry related, not research	Not chemistry related	Undecided
Women	2nd Year (13)	I	𝍸 IIII	III		𝍸 III	III	I	I
	3rd Year (15)	II	𝍸 III	𝍸		𝍸 II	II	I	𝍸
	Completed (12)	𝍸	𝍸	II	II	II	𝍸 II		I
	TOTAL (40)	8	22	10	2	17	12	2	7
Men	2nd Year (14)	IIII	𝍸 𝍸		𝍸 I	III	II	I	II
	3rd Year (15)	𝍸 III	𝍸 II		𝍸 I	II			𝍸 II
	Completed (12)	𝍸 III	IIII		𝍸 III	II	I	I	
	TOTAL (41)	20	21	0	20	7	3	2	9

NB. The Doctoral Study Experience was rated as "good", "mixed" or "poor" by the researcher (who rated doctoral experiences based on the impression she got from reading the transcript of each participant) and not by participants.

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