International Journal of Gender, Science and Technology
http://genderandset.open.ac.uk

A Survey of Chemistry and Physics Postdoctoral Researchers' Experiences and Career Intentions

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ABSTRACT
This survey was designed to investigate whether male and female postdoctoral researchers (PDRs) in the U.K. in physics and chemistry had different experiences and whether this then affected their long-term career intentions. A total of 776 PDRs completed the survey. Most of the analysis was confined to those who stated their gender and declared that they worked in a chemistry or physics department. Statistical significance was tested using Chi-squared test. Overall, more differences were found between chemists and physicists than between the genders, indicating that there may be important cultural differences between the disciplines. Where gender differences were found, they were generally greater between male and female chemists than between male and female physicists. The data also highlighted that appraisal, induction and mentoring were still not commonplace in many departments and less than half of postdoctoral researchers actually felt valued within their department. It is clear, therefore, that more needs to be done to improve the experience of PDRs in physics and chemistry, regardless of gender or discipline

KEYWORDS
universities; careers; gender; postdoctoral researchers; physics; chemistry

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INTRODUCTION

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% (DTI, 2002). 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 – women 'leak out' and are lost to science at a faster rate than men (US National Academies Report, 2007; ETAN Report, 2000; She Figures, 2009).

Academic chemistry and physics provide two contrasting examples of career pipelines.

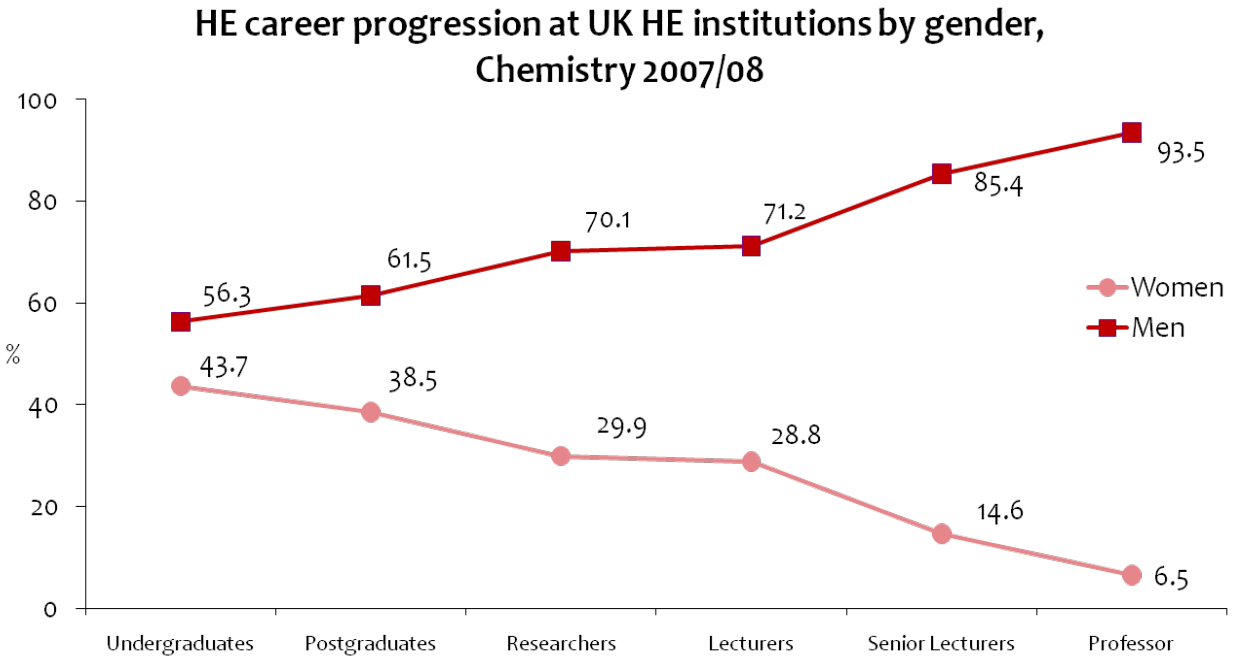

Figure 1: *The chemistry higher education pipeline (Source: Higher Education Statistics Agency (HESA)[1] Staff Data)*

Figure 1 illustrates that the proportion of female undergraduates in chemistry is around 44% and compares well with the proportion of women who take A level[2] chemistry (48%). However, there is a faster leakage of women than men in moving from A level, to undergraduate and then postgraduate level. Thereafter there is a

more significant relative leakage of women than men in moving from postgraduate to researcher level in chemistry, and this has been the subject of much research.

In comparison with the proportion of female chemistry undergraduates, chemistry currently has a low proportion of female professors. The snapshot data on academic grades do not by themselves demonstrate that women 'leak' from the academic pipeline as the permanent academic grades typically represent a career of 35 years or so. Figure 2 presents data on the proportions of female staff in academic chemistry at different grades over a 13 year period. (Note: HESA stopped requiring institutions to provide data broken down into academic grades, excepting professors, for the academic year 2008/09 onwards. For 2008/09 and 2009/10 staff grades were identified using staff function, but it was not possible to split lecturers and senior lecturers.)

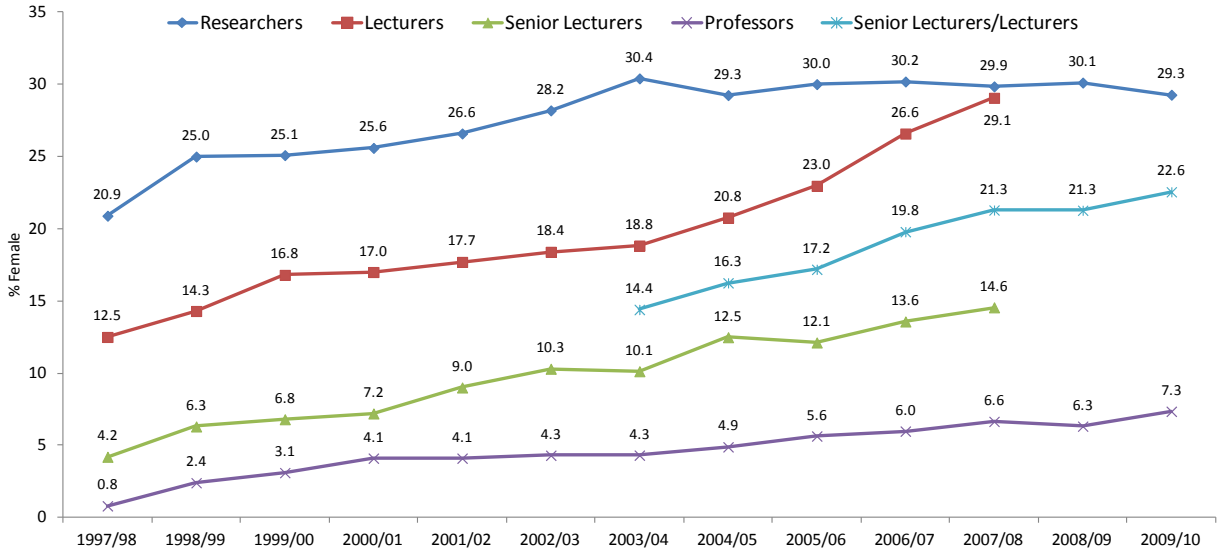

Figure 2: *Proportion of female staff in the chemistry cost centre at each grade 1997/98 to 2009/10 (Source: HESA Staff Data)*

The proportion of female staff at lecturer, senior lecturer and professor grades has been steadily rising over the period of time under consideration, but the proportion of female researchers has stabilised at about 30% since 2003/04. The proportion of female lecturers in 2007/08 was on par with the proportion of female researchers in chemistry. It is not possible to conclude whether or not there is significant 'leakage' of female staff using the data in Figure 2: the data do suggest that female staff are progressing through the academic grades but the data do not show whether men and women progress at similar rates.

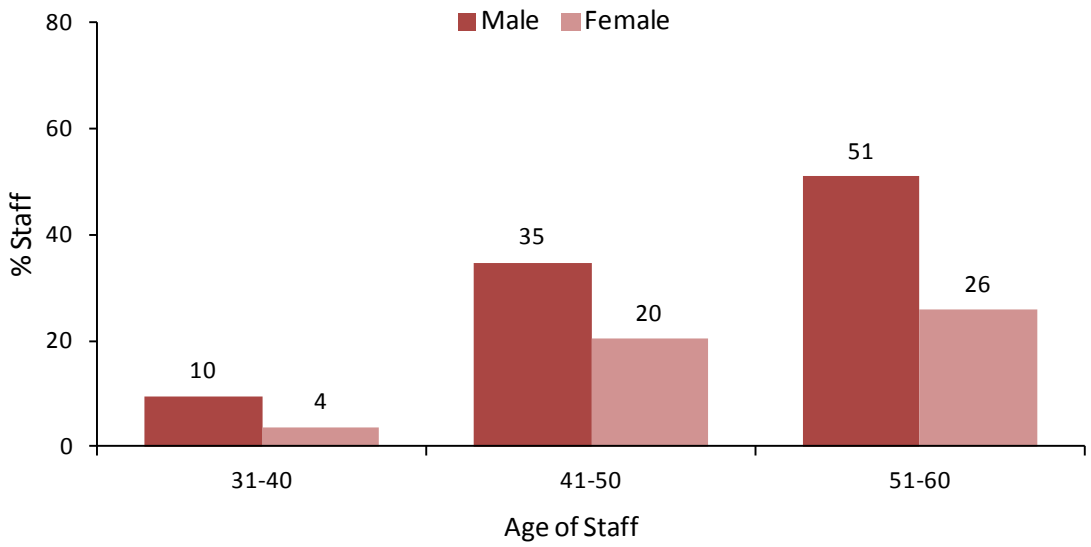

Figure 3: *Proportion of male and female permanent academic staff who are professors by age in the chemistry cost centres 2009/10 (Source: HESA Staff Data)*

Figure 3 presents data on the proportion of male and female permanent academic staff (lecturers, senior lecturers and professors) who are professors in chemistry within specific age bands. In the three age bands displayed, smaller proportions of women permanent academic staff are at professorial level than men. This suggests that when the age of staff is taken into account, women are less likely to have progressed to professorial level than men. This may be due to a number of factors, including the possibility that women have spent more time than men caring for children, and that they may have been more reluctant than men to apply for promotion.

Overall, chemistry attracts a relatively high proportion of female students onto undergraduate courses but is less successful at retaining women through into academic careers. Data also suggest that women are less likely than men to progress to the professorial levels.

In contrast to chemistry, physics recruits half the proportion of female undergraduates (22%) although this does compare well with the proportion of women taking A level physics (22% in 2009). Figure 4 illustrates that women are retained in physics to the same extent as men through to postgraduate level but there is a drop in the proportion of women at researcher level; both subjects have similar proportions of women at professorial level.

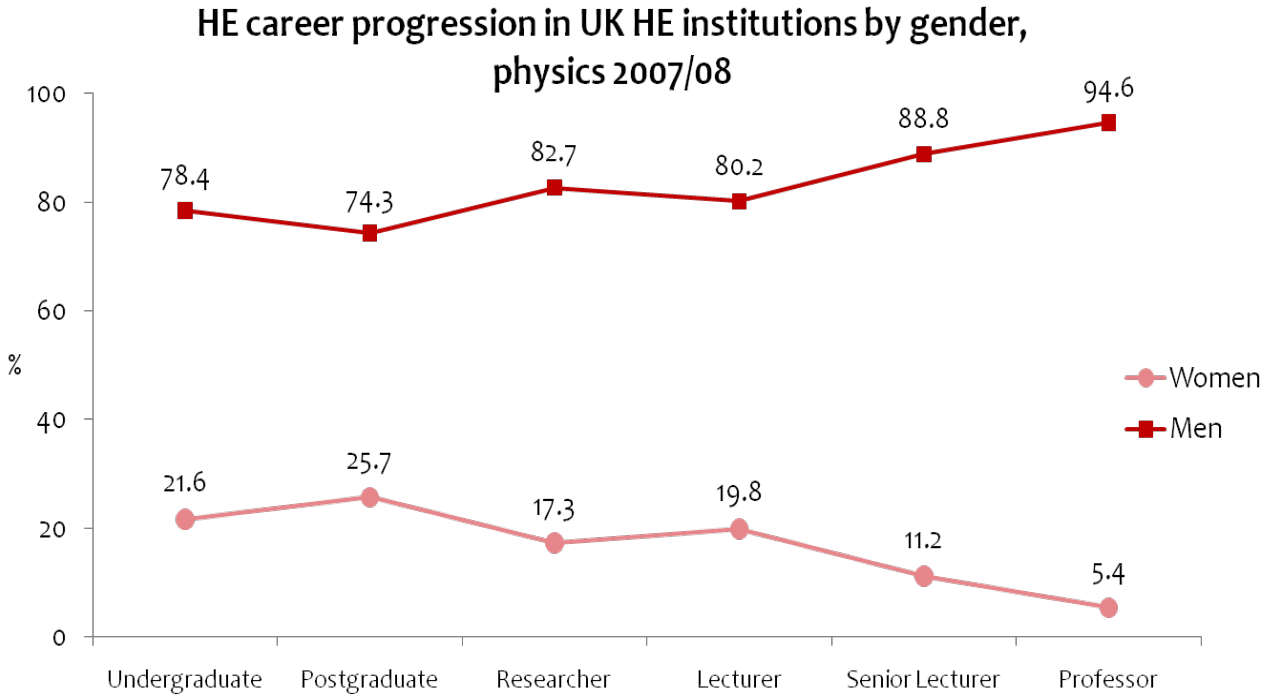

Figure 4: *The physics higher education pipeline (Source: HESA Staff Data)*

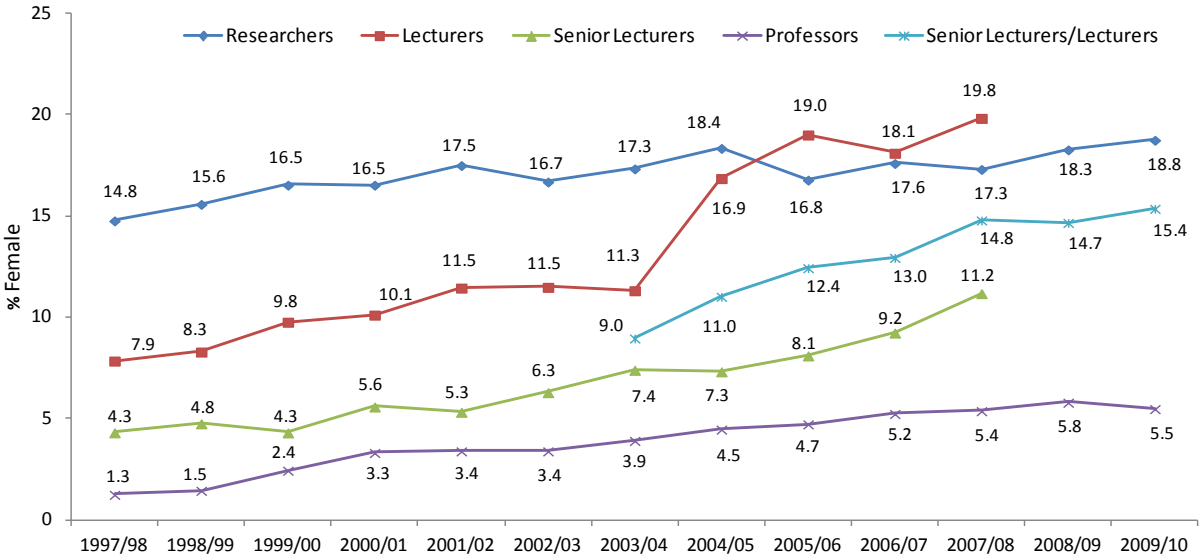

Figure 5: *Proportion of female staff in the physics cost centre at each grade 1997/98 to 2009/10 (Source: HESA Staff Data*)

Figure 5 presents data on the proportions of female staff in academic physics at different grades over the same 13 year period as that presented for chemistry in Figure 2.

Like chemistry, in physics the proportion of female staff has been steadily rising over the period of time under consideration. The proportion of female lecturers is now higher than the proportion of female researchers in physics.

Figure 6: *Proportion of male and female permanent academic staff who are professors by age in the physics cost centres 2009/10 (Source: HESA Staff Data)*

Figure 6 presents data on the proportion of male and female permanent academic staff (lecturers, senior lecturers and professors) in physics within specific age bands who are professors. Like chemistry in the three age bands displayed, smaller proportions of women permanent academic staff are at professorial level than men

Overall physics, in contrast to chemistry, is more successful at retaining women into permanent higher education careers but has more difficulty in recruiting them into undergraduate courses.

More detailed data analysis is required to establish whether women leave academic careers to a greater extent than men once they have obtained permanent positions. However, in both chemistry and physics the proportion of women has been rising at all academic grades, but data suggest that when age is taken into account, women do not progress to professorial level to the same extent as men.

The Royal Society of Chemistry (RSC) originally became interested in 'the leaky pipeline' when their analysis of Higher Education Statistics Agency (HESA) data showed that female attrition was notably higher in chemistry, compared with other sciences and commissioned a study to examine why (Royal Society of Chemistry, 1999). In 2006 the RSC ran a survey of PhD students to provide further insights into female attrition from chemistry (Royal Society of Chemistry, 2008) and found that many female chemistry PhD students were put off careers in scientific research, either in industry or academia, during their PhD and that a significantly

smaller proportion of females than males wished to pursue an academic career. The qualitative responses to the survey hinted that female chemists were being put off the by the 'all-consuming' nature of academic research, by isolation, and by the perceived incongruity between an academic science career and motherhood. Follow-up qualitative work carried out in 2008 (Royal Society of Chemistry, 2009) identified a number of factors that deterred female chemists more than their male peers from remaining in research. These included: being more affected by standard 'supervision issues', such as enjoying little pastoral care; encountering more significant supervision issues; isolation and exclusion, partly caused by the culture of their research group; and concerns about perceived poor experimental success rates.

In contrast to the results for chemistry, a survey of molecular bioscience PhD students (Biochemical Society, 2009) found that there was no evidence that women were deterred during their PhD from entering a research career in molecular biosciences.

These findings prompted a number of questions about how the experiences of male and female postdoctoral researchers (PDRs), the next step in the academic career pipeline, might affect their long-term career intentions. The Royal Society of Chemistry and the Institute of Physics decided to work together to research this question. The research was particularly focused on whether PDRs in chemistry and physics had different experiences and whether men and women reacted differently to these experiences in terms of their career intentions.

Physics and chemistry are both classified as physical sciences and as such share some characteristics. For example, relatively large proportions of both physics and chemistry undergraduates go on to doctoral studies.

This article has been adapted for publication from a report to the Institute of Physics and the Royal Society of Chemistry "Mapping the Future: Survey of Chemistry and Physics Postdoctoral Researchers' Experiences and Career Intentions". The full report and a summary report are available for download (Institute of Physics, 2011).

METHODOLOGY

A web-based questionnaire, based on the questionnaires used in the 2006 study of chemistry and the 2008 study of molecular bioscience PhD students were developed. It was designed to collect information on the characteristics and personal circumstances of the respondents, where they had studied, how long they had been undertaking postdoctoral research, their plans for the future and what opportunities they had had for career development and training. In addition there were questions on appraisal, mentoring, and teaching opportunities and their views of the culture of the academic department in which they worked. A paper form of the questionnaire was piloted with a group of PDRs from the Chemistry Department at Imperial College, London.

All physics and chemistry departments in the UK were contacted to ask whether they would participate in the study. 30 physics departments and 29 chemistry departments agreed to take part and to disseminate the questionnaire to their PDRs. The survey ran from March to April 2010. A prize draw, with Amazon vouchers as prizes, was offered as an inducement to complete the questionnaire. A total of 776 completed questionnaires were completed by the closing date.

DEMOGRAPHICS

The respondents were split evenly between chemistry (376) and physics (370), with 30 respondents specifying that they were affiliated to other departments. 34% of the chemists and 25% of the physicists were female. 45% of the chemists and 56% of the physicists identified themselves as British. Around 85% of those who identified themselves as British reported their ethnicity was White British. Less than 1% of respondents disclosed that they had a disability.

97% of respondents worked full-time. Women were more likely to work part-time than men: around 1 in 20 chemists and 1 in 10 physicists worked part-time. Female researchers were generally less likely to be married and less likely to have children than male researchers, although female researchers were also generally younger than their male counterparts.

When the demographics of the sample were compared with HESA data (HESA, 2010), it was found that the sample was broadly representative of the HESA population although women were slightly over represented, and the sample was younger than the population used in the HESA data.

ANALYSIS

Most of the analysis was confined to those who stated their gender and declared that they worked in a chemistry or physics department. Statistical significance was tested by using a chi-squared test with one degree of freedom. Where respondents were able to select more than one option the test was carried out on whether men or women selected a specific option versus whether they did not select that option as independent categories. Where appropriate the significance levels are quoted in parentheses.

The postdoctoral research experience: time spent as a PDR

Among respondents, on average chemists had spent less time as a PDR than physicists and women had spent less time as a PDR than men. Over 70% of respondents had been undertaking postdoctoral research for less than four years and almost 15% for over seven years. 45% of respondents were on their first contract and 29% had worked on three or more contracts.

In terms of the length of time as a PDR, the most striking differences were between male physicists and female chemists, with male physicists being twice as likely as female chemists to have been a PDR for seven years or more and almost three times as likely to have been a PDR for more than ten years (Figure 7).

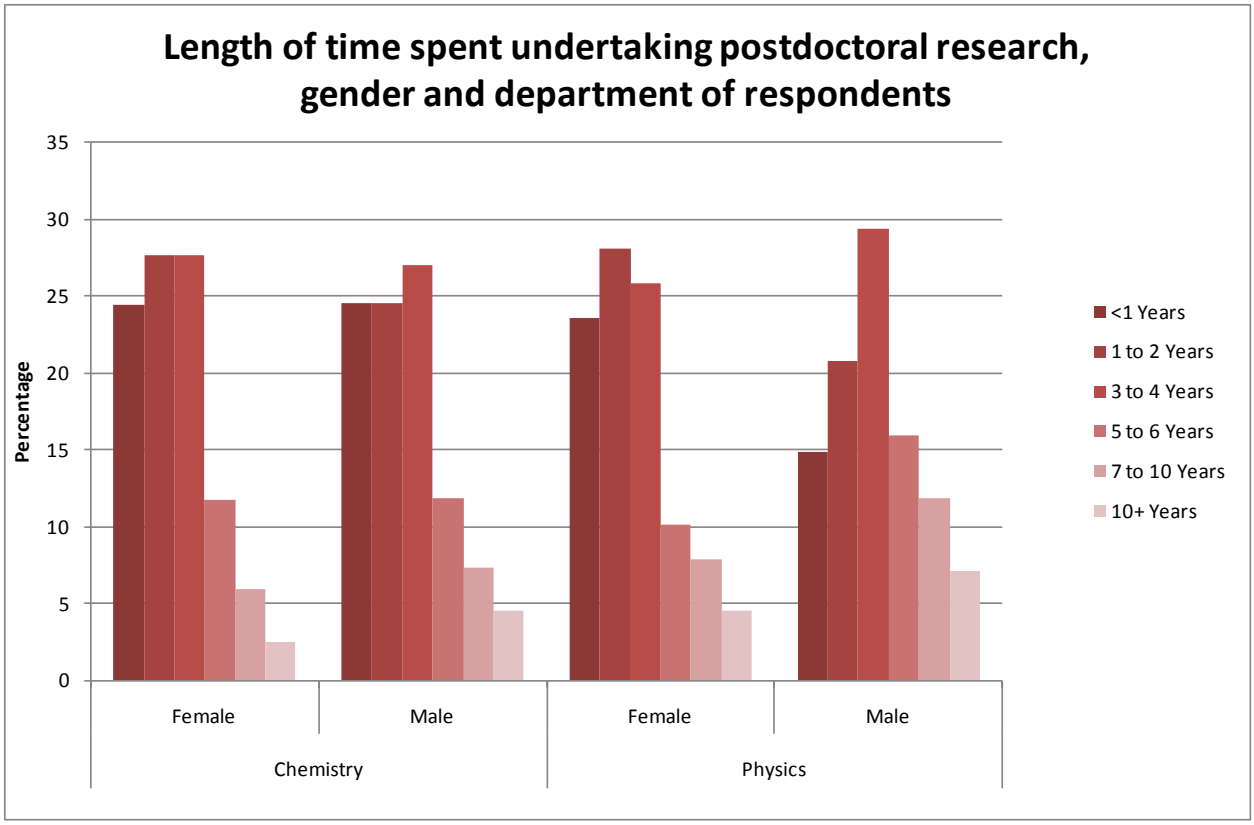

***Figure 7**: Length of time spent undertaking postdoctoral research, gender and department of respondents*

Motivations for undertaking postdoctoral research

Respondents were asked to select from a list the two main reasons why they were undertaking postdoctoral research. The most popular reason selected was 'Out of interest and enthusiasm for science', with 80% of physicists and 67% of chemists selecting this reason. This finding is in line with other work on the motivations of chemists (Purcell, Atfield, Ball and Elias, 2009) and in line with a questionnaire issued by the Science and Technology Facilities Council (STFC), which found that more than 95% of both male and female STFC-funded postgraduate students cited enthusiasm for their subject as the reason they were undertaking postgraduate research (STFC, 2010). The second most popular reason selected was to gain a permanent academic post. Men (53%) were statistically significantly ($p<0.01$) more likely than women (42%) to select this reason.

79% of respondents indicated that they were pleased with the decision to undertake postdoctoral research. This group were then asked the main reason why, and the most popular reasons given were 'I enjoy researching my topics' and 'I enjoy the challenge of advancing knowledge'. Women were more likely than men to say that they, 'Enjoyed the academic environment'.

All respondents were asked to select from lists all the 'upsides' and 'downsides' of undertaking postdoctoral research that applied to them. Four 'upsides' were

selected by over half the respondents: ‘Flexible working hours’; ‘Exciting and interesting projects’; ‘Collaboration potential’; and ‘Travel and networking opportunities’. There were few gender differences. By far the most popular ‘downside’ selected was ‘No job security’, which was selected by 78% of respondents. Female physicists were significantly more likely to select ‘Working long and irregular hours’ and ‘Isolation’, as a downside than male physicists ($p<0.05$) and more likely to select ‘Isolation’ than female chemists.

Next Steps: the effect of postdoctoral research on short-term career intentions

Around 12% of respondents had already accepted an offer for their next job, with the majority of these (80%) staying in academia, either on another research contract or moving into a fellowship or lectureship. Those that had not accepted a job offer were questioned about their intentions in more detail.

When asked if undertaking postdoctoral research had any effect on their intentions to continue in a career in research science, 40% of respondents said they were now more intent and 36% were now less intent. There were no differences between male and female physicists or between physicists and chemists but there was a significant difference ($p<0.05$) between the male (32%) and female chemists (46%) reporting that they were now less intent on career in research science.

Results were analysed comparing those on their first contract with those on their second or subsequent contracts. For chemists, those on their second or subsequent contracts were significantly less enthusiastic ($p<0.01$) about careers in research science, with the difference being particularly striking for women: 28% of female chemists on their first contract, and 61% of those on their second or subsequent contracts were less intent on pursuing a career as a research scientist. In contrast, there was relatively little difference between female and male physicists, although again those on their second or subsequent contracts were slightly less enthusiastic towards research careers than those on their first contract, and the difference was slightly greater for women than men.

89% of respondents indicated that they would seek employment in a role that required a scientific background. Of these, the majority in both chemistry and physics would seek a role in academia, with almost 76% of chemists and 79% of physicists saying that they would seek employment in a university (as a PDR/lecturer). Table 1 outlines the top 5 areas in which chemists and physicists would seek scientific employment.

Table 1: *Sectors of employment sought for chemists and physicists, by gender and contract**

Sectors Employment sought in as a research scientist		First PDR Contract			Subsequent PDR Contract			Overall
		Female	Male	Overall	Female	Male	Overall	
Chemistry	University (not as a PDR/lecturer)	30.8%	34.1%	32.6%	21.6%	18.3%	19.6%	25.8%
	University (as a PDR/lecturer)	71.2%	78.0%	75.7%	70.6%	77.9%	75.9%	75.8%
	Chemical Industry	21.2%	17.6%	18.8%	25.5%	21.2%	22.8%	20.9%
	Research Institute	23.1%	18.7%	20.8%	15.7%	18.3%	18.4%	19.5%
	Pharmaceutical industry	21.2%	14.3%	16.7%	19.6%	20.2%	19.6%	18.2%
	Sample size	**52**	**91**	**144**	**51**	**104**	**158**	**302**
Physics	University (not as a PDR/lecturer)	25.6%	29.5%	28.8%	35.3%	27.6%	29.0%	28.9%
	University (as a PDR/lecturer)	74.4%	76.9%	76.3%	67.6%	83.5%	80.2%	78.6%
	Research Institute	20.5%	15.4%	17.8%	20.6%	21.3%	21.0%	19.6%
	Physics Industry	20.5%	20.5%	20.3%	11.8%	16.5%	15.4%	17.5%
	Pharmaceutical industry	17.9%	16.7%	16.9%	8.8%	11.0%	10.5%	13.2%
	Sample size	**39**	**78**	**118**	**34**	**127**	**162**	**280**

*Respondents were asked to select all the sectors/roles that applied

Long-term career plans

When asked to indicate what they thought they were most likely to be doing in the longer-term future, 63% of chemists and 66% of physicists believed that they were most likely to be on a permanent academic contract in 6-10 years' time. Table 2 highlights the top four long-term career choices for chemists and physicists respectively.

Overall 65% of female chemists and 69% of male chemists selected 'Academic on a permanent contract'. However, when results were analysed between those on their first and those on second or subsequent contracts there was a significant difference ($p<0.01$) between male (66%) and female (44%) chemists on second or subsequent contracts selecting this option. Female chemists on second or subsequent contracts were almost twice as likely to select 'Scientist: industry/ commerce' than those on their first contract.

Table 2: *Longer term career plans of chemistry and physics postdoctoral researchers*

Jobs which PDRs are most likely to be doing in 6-10 years time*		First PDR Contract			Subsequent PDR Contract			Overall
		Female	Male	Overall	Female	Male	Overall	
Chemistry	Academic on a permanent contract	64.5%	69.2%	67.7%	43.8%	66.4%	58.3%	63.2%
	Scientist: industry/ commerce	21.0%	30.0%	27.1%	40.6%	33.6%	36.1%	31.5%
	Continue undertaking postdoctoral research	17.7%	18.5%	18.2%	12.5%	11.2%	11.7%	15.1%
	Scientist: public sector	9.7%	13.8%	12.5%	10.9%	18.1%	15.6%	14.0%
	Sample size	**62**	**130**	**192**	**64**	**116**	**180**	**372**
Physics	Academic on a permanent contract	56.5%	65.2%	63.3%	55.3%	75.7%	69.6%	66.0%
	Scientist: industry/ commerce	21.7%	26.8%	25.7%	12.8%	29.7%	24.7%	25.3%
	Continue undertaking postdoctoral research	17.4%	17.7%	17.6%	29.8%	24.3%	25.9%	21.2%
	Scientist: public sector	19.6%	15.2%	16.2%	10.6%	16.2%	14.6%	15.5%
	Sample size	**46**	**164**	**210**	**47**	**111**	**158**	**368**

*Respondents were asked to select no more than two choices

The pattern for physics was different. 57% and 65% of female and male physicists respectively on their first contract saw themselves on a permanent academic contract in 6-10 years' time. For those on subsequent contracts the respective proportions were 55% and 76%, which is a statistically significant difference ($p<0.01$). Here, while the proportion of women remained essentially the same, men on subsequent contracts were more likely to see themselves on permanent academic contracts. Among physicists and chemists, male physicists were the group most likely to see themselves as an academic on a permanent contract in 6-10 years' time.

Factors influencing career choices

Respondents were asked how important it was to have a career that involved a number of specified factors and were asked to rate these factors as very important, important, somewhat important, or not important.

In general, women ranked 'Safe working environment', 'Good professional development opportunities', 'Flexible working opportunities' and 'Be near my partner's place of work/study' higher than men. They also ranked 'Access to state-of-the-art equipment/ resources' and 'Opportunities to publish' lower than men. There were some differences between the rankings provided by male and female chemists and male and female physicists but these were not significantly different from those listed above.

Career Development: awareness of career opportunities and careers advice
Respondents were questioned about their awareness of career options. Almost 90% of respondents rated their awareness of career opportunities within academia as adequate or better but only 56% of respondents rated their awareness of career opportunities outside academia as adequate or better. In fact, 36% of chemists and 51% of physicists described their knowledge of the latter as poor or very poor. Female and male physicists rated their awareness in a very similar way although female physicists' knowledge of opportunities outside academia improved after their first contract.

38% of respondents reported that they received careers advice prior to undertaking postdoctoral research, with a significant difference between female (47%) and male (38%) physicists ($p<0.05$). 76% of those who had taken advice had taken it from their PhD supervisors, 46% from other academic staff, and 45% from the university careers service. Only 19% of respondents overall had taken advice from 'professional' sources. A slightly higher proportion of respondents reported having taken advice during their current contract (45%), with female chemists slightly more likely to have received advice than males.

Appraisal
Respondents were questioned about their knowledge of their institutional appraisal systems as well as their own personal experiences of appraisal. A significantly lower ($p<0.01$) proportion of chemists (55%) than physicists (73%) reported that there was an appraisal system in their university, albeit not necessarily for PDRs. Examination of data for individual institutions suggests that all those institutions in the survey with reasonable numbers of respondents (5 or more) had one or more respondents report that there is an appraisal system. In fact the majority of HEIs do have appraisal schemes which apply to PDRs and it is also worth noting that in some institutions well over 90% of respondents said that there was an appraisal system which suggests that some institutions are doing a better job than others in communicating information about appraisal to postdoctoral researchers.

When respondents who replied that there was an appraisal system in their institution were questioned specifically about appraisal for postdoctoral researchers, again chemists were less sure than physicists about appraisal (67% of chemists and 84% of physicists reported that PDRs were normally appraised). 73% of those respondents who reported that PDRs were appraised said that appraisal took place once a year, 11% reported that it took place every 2 years, and another 11% that it took place twice a year. Although some respondents reported that they had been appraised regularly over the length of their contract(s), a number of others had only been appraised intermittently. Overall 44% of all respondents reported that they had been appraised at some point in their postdoctoral career.

Physicists were more likely than chemists to have their appraisal carried out by someone other than their PI/Group Leader. In turn, female physicists were less likely than male physicists to report being appraised by their supervisor/PI (Table 3).

Table 3: *Who normally carries out appraisal, by department and gender*

Who carries out appraisals	Chemistry			Physics			Overall
	Female	Male	Overall	Female	Male	Overall	
PI/supervisor	83.3%	81.7%	82.4%	44.9%	71.1%	64.5%	71.3%
Another member of staff	16.7%	18.3%	17.6%	55.1%	28.9%	35.5%	28.7%
Sample sizes	**42**	**82**	**125**	**49**	**152**	**203**	**328**

Of those who had been appraised 35% found the appraisal process useful and relevant, with similar proportions reporting it was somewhat useful and it was not useful respectively. Respondents were more likely to find the appraisal experience useful and relevant if it was carried out by their Supervisor/Principle Investigator (PI); thus it was not surprising that female physicists were the group least likely to find the appraisal useful or relevant.

Respondents were asked to give reasons in a free text box as to why they found the process useful or not. Those who found appraisal useful generally tended to report that it centred on having the opportunity to review and set goals, and to receive careers advice. Those that did not find appraisal useful tended to say that it was merely a box-ticking exercise or a formality. Interestingly, when those that were not appraised were asked if they would like to be almost 33% of both men and women said no.

Development of Transferable Skills

Respondents were questioned about the development of their transferable skills (Table 4). Just under two thirds of respondents reported that they were encouraged to undertake activities to develop their transferable skills. There was little difference between chemists and physicists, although a slightly higher proportion of female physicists reported that they were encouraged compared to other groups. Relatively small proportions of all groups said that they were not encouraged. A slightly higher proportion of female chemists reported that they were not encouraged relative to other groups.

Table 4: *Whether or not respondents are encouraged to undertake activities to develop their transferable skills by department and gender*

Encouraged to undertake activities to develop transferable skills	Chemistry			Physics			Overall
	Female	Male	Overall	Female	Male	Overall	
Encouraged	63.5%	62.2%	62.0%	72.0%	64.7%	66.5%	64.2%
Not encouraged	8.7%	5.7%	6.6%	1.1%	4.4%	3.5%	5.1%
Neither encouraged nor discouraged	27.8%	32.1%	31.4%	26.9%	30.9%	30.0%	30.7%
Sample size	**126**	**246**	**376**	**93**	**275**	**370**	**746**

All respondents except those who were not encouraged to undertake development activities were asked which activities from a list they had undertaken during postdoctoral research at their current institutions. There were some differences between the responses of male and female physicists and chemists with the most noticeable difference being between male and female physicists' training course attendance and teaching with larger proportions of male (53%) than female (43%) physicists reporting that they had attended training courses, and undertaken teaching (64% and 52% respectively). The latter difference is statistically significant ($p<0.05$).

The proportions of both chemists and physicists reporting that they had undertaken teaching increased with experience. For example, 63% of physicists and 56% of chemists with 1 to 2 years' postdoctoral research experience reported undertaking teaching, in contrast to 76% and 83% of physicists and chemists respectively with 5 to 6 years' experience.

Mentoring Schemes

Respondents were asked whether or not they were aware of a mentoring scheme at their institution. 32% of respondents reported that there was a scheme, and 63% said that they were unaware of a scheme. There was little difference between the awareness of male and female chemists (36% and 33% respectively), but female physicists (38%) were more likely to report that there was a scheme than male physicists (27%): male physicists were also more likely than female physicists to say that they were unaware whether or not there was a scheme. Overall less than 5% of PDRs had participated in a mentoring scheme in their current institution.

Applying for Fellowships

Fellowships are important to an academic career in that they provide the opportunity to develop as an independent researcher. Respondents were asked whether or not they had ever applied for a fellowship: overall half reported that they had done so. The survey did not define what was meant by a fellowship so there might have been some confusion among respondents as to the exact meaning of the term fellowship.

Around 60% of female physicists reported that they had applied for a fellowship compared to 52% of male physicists. In contrast, 48% of female chemists and 47% of male chemists reported that they had applied for a fellowship.

Analysis of whether respondents had applied for a fellowship and length of time they had spent as a PDR suggests that for a given length of service women are more likely to have applied for a fellowship than men. This may be interpreted in a number of ways: perhaps only women who have a chance of gaining a fellowship remain in postdoctoral researcher positions, or perhaps women are more likely to apply for fellowships than men. Of note is that women in their first year of undertaking postdoctoral research in physics are much more likely to have applied for a fellowship than men in a similar position (46% and 27% respectively).

55% of all respondents had been encouraged to apply for fellowships: 56% and 52% of female and male chemists respectively had been encouraged, and 62% and 54% of female and male physics respectively had been encouraged.

86% of respondents had been encouraged to apply for fellowships by their PI and 37% by other academic staff, 24% by other postdoctoral researchers, and 15% by the head of department. Physicists reported that they were more likely than chemists to be encouraged by other academic staff (37% and 32% respectively), other postdoctoral researchers (27% and 21% respectively) and the head of department (20% and 11% respectively). This is statistically significant at the $p<0.05$ level.

There were few gender differences for chemists, but more for physicists. Female physicists are more likely to be encouraged by the head of department, and less so by other academic staff. (This is statistically significant at the $p<0.01$ level.) Perhaps female physicists are more inclined to receive encouragement from more formalised routes; it is possible that this is linked to the isolation reported earlier when considering the ‘downsides’ of undertaking postdoctoral research.

The data also underline the importance that postdoctoral researchers put on the opinions of their supervisors.

Culture of departments

While only 5% of PDRs described their relationship with their supervisor as poor or very poor, only 28% of respondents then indicated that their relationship could not be enhanced. Although there were no significant differences between the responses of physics and chemists, or between women and men, female physicists were the group least likely to report their relationship as excellent.

Respondents were asked to select from a list the ways in which their relationship with their supervisor could be improved. 28% of respondents indicated that their relationship with their supervisor could not be enhanced but women were less likely than men to select this option: this does mean that over 70% of respondents believe that the relationship with their PI/group leader could be enhanced to some degree.

Relatively few respondents indicated that they would like 'Less support and more independence': 'More general advice and mentoring', 'More research support', and 'More careers advice' were selected by 36%, 31% and 30% of respondents respectively. Women were more likely than men to select that their relationship with their supervisor could be enhanced by 'More general advice and mentoring' and 'More research support' and female physicists were more likely than male physicists to select 'More careers advice'. None of the differences noted were significant.

Table 5: *Ways in which relationship with supervisor could be enhanced (respondents could select all that applied)*

How relationship with supervisor can be enhanced	Chemistry			Physics			Overall
	Female	Male	Total	Female	Male	Total	
More general advice & mentoring	38.7%	33.6%	35.4%	40.4%	35.3%	36.8%	36.1%
More research support	35.3%	26.6%	29.4%	38.2%	29.7%	31.8%	30.6%
More careers advice	29.4%	32.0%	30.8%	36.0%	27.1%	29.2%	30.0%
Could not be enhanced	20.2%	29.5%	26.7%	24.7%	30.1%	28.7%	27.7%
Less general advice/more independence	3.4%	9.4%	7.6%	6.7%	5.2%	5.6%	6.6%
Other ways	5.9%	5.7%	5.7%	4.5%	7.1%	6.4%	6.1%
Sample size	**119**	**244**	**367**	**89**	**269**	**359**	**726**

50% of respondents overall reported that they had a departmental induction when joining their current department. Around 41% of those staying in the same group as their PhD and 52% of those moving groups reported that they had a departmental induction. However, only 10% of female chemists staying in the same group as their PhD reported that they had an induction, compared to 57% of males. 90% of female chemists and 77% of female physicists staying in the same group reported that they did not have an induction, compared to 43% and 55% of chemistry and physics males respectively. For those that moved groups, induction was more prevalent but still not regular with 58% of chemists and 47% of physicists reporting that they had received an induction, again males were more likely to report they had an induction than females (Table 6). 66% of respondents found the induction useful, with chemists significantly more likely to report this than physicists ($p<0.05$).

Table 6: *Whether respondents had received a departmental induction*

	Chemistry			Physics			Overall
	Female	**Male**	**Overall**	**Female**	**Male**	**Overall**	
Same Group as PhD							
Departmental induction	10.0%	56.8%	42.4%	23.3%	44.6%	39.5%	40.6%
No departmental induction	90.0%	43.2%	57.6%	76.7%	55.4%	60.5%	59.4%
Sample sizes	**20**	**44**	**66**	**30**	**83**	**114**	**180**
Different Group as PhD							
Departmental induction	54.3%	60.7%	58.4%	41.3%	49.5%	47.3%	53.4%
No departmental induction	45.7%	39.3%	41.6%	58.7%	50.5%	52.7%	46.6%
Sample sizes	**105**	**201**	**308**	**63**	**192**	**256**	**564**

47% of postdoctoral researchers did not know whether there was PDR representation within their department at important meetings.

When asked about supervising PhD students and teaching, much larger proportions of chemists than physicists (65% and 47% respectively) said that they were expected to supervise PhD students and a slightly higher proportion of physicists than chemists said that they were not expected to do so, but did (27% compared to 22% respectively). Male physicists were the most likely to report the latter (29%). Only 12% of respondents stated that this responsibility was formalised and recognised and 65% said they would like it to be. 73% of respondents reported that they had the opportunity to teach, with 82% of physicists and 63% of chemists reporting that they had this opportunity.

Status within departments

PDRs were asked about their status within their departments, whether they felt more like a staff member, a student, or neither, and whether they thought PDRs were generally well regarded. 59% of physicists reported that they felt more like staff than students and 11% reported they felt more like students than staff. In contrast, 43% of chemists reported feeling more like staff than students, and 17% said they felt more like students. There were differences between male and female chemists with 48% and 38% respectively reporting feeling more like staff than students. 23% of female chemists and 15% of male chemists reported feeling more like students than staff.

Around 40% of PDRs felt that they were well regarded within their department, 36% had mixed opinions on the issue and 11% felt that PDRs were not well regarded. There were statistically significant ($p<0.01$) differences between chemists

and physicists feeling well regarded in their departments (34% and 45% respectively). While there was very little difference in the views of male and female physicists, there were larger, but not significant, differences in the opinions of male and female chemists: 29% of female and 37% of male chemists felt well regarded (Figure 8).

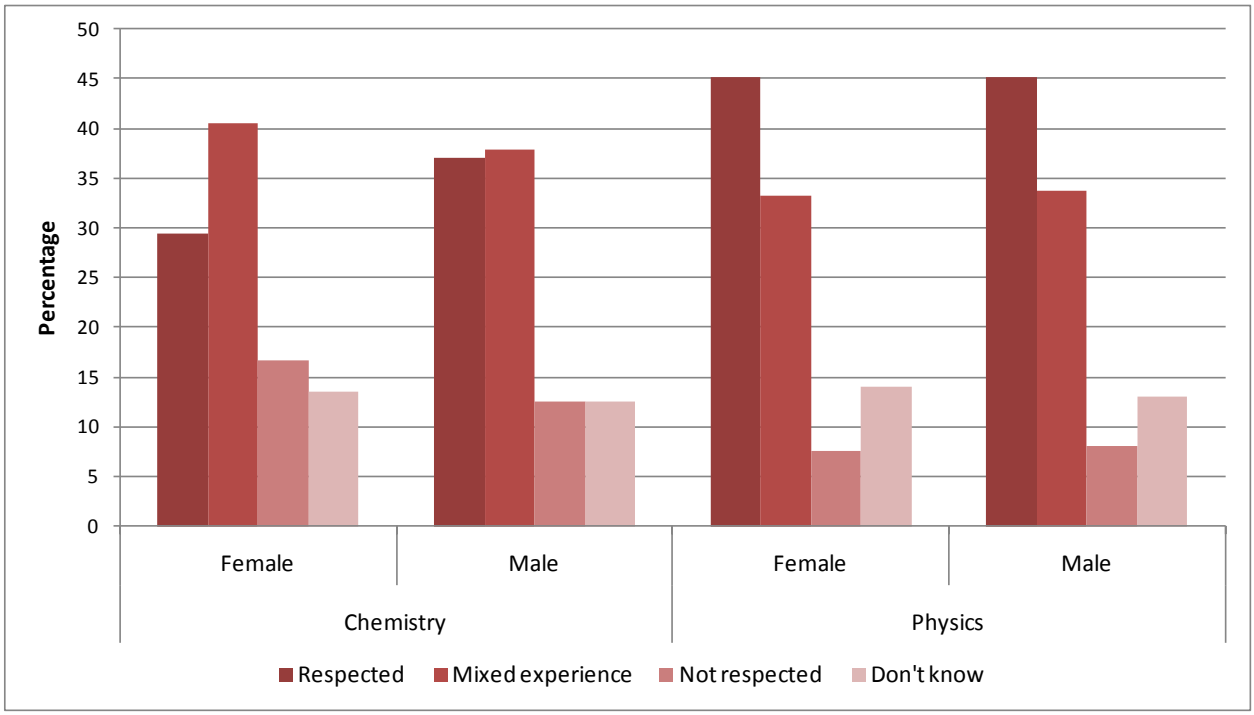

***Figure 8**: Respondents' opinions as to the regard with which postdoctoral researchers are held*

Respondents were asked to explain their responses as free text: many reported that they were seen as 'expendable' or there to be 'dumped on' by academics. Those that reported more positive feelings said that their opinions were valued and respected, and they were treated seriously by their PIs.

One factor that was not explored in the research was how the gender structure in the department, or the gender composition of research groups, affected how postdoctoral researchers felt about their status. This is something that could be explored in any follow up research.

DISCUSSION

One of the main reasons for carrying out this survey was the study by the RSC, which found that a significant proportion of female PhD chemists, and a smaller proportion of male chemists, disliked the process of carrying out scientific research and this drove many of them to decide not to pursue research careers although they still wished to have careers which utilised their science. The research also found that a number of those who wanted research careers did not want academic

careers. Women in particular did not see many role models with whom they could identify and felt that the long-hours culture was incompatible with raising a family.

This study was undertaken to examine the experiences and career intentions of chemistry and physics postdoctoral researchers, and to find out whether there were differences between chemists and physicists and between men and women.

Corroborating previous studies that found that the majority of chemistry undergraduate (Purcell, Atfield, Ball and Elias, 2009) and PhD students (Royal Society of Chemistry, 2008), as well as physics undergraduate (Institute of Physics, 2001) and PhD students (STFC, 2010) were motivated by their interest in science, the results of this study have now shown that the majority of postdoctoral researchers are also driven by interest and enthusiasm for science, although a higher proportion of physicists fell into this category than chemists.

The main driver in the decision-making of those who choose to study science and work as researchers in universities was interest in their subjects. Indeed, the majority of both the physics and chemistry PDR populations were pleased with their decision to carry out postdoctoral research and most of these individuals indicated that this was because they enjoyed advancing knowledge, the challenge of research, or the academic environment itself. Nevertheless, by far the most commonly selected negative factor of undertaking postdoctoral research was lack of job security. A useful framework to interpret the findings of this study and the earlier work on PhD students is the interplay of three competing factors: a passion for science; a like or dislike of the research/academic culture; and the need to have a career with some stability and security. The degree to which these three factors interplay then affects individuals' decision making.

There was no significant difference between chemists and physicists in terms of the effect that undertaking postdoctoral research had on their intentions to stay in research science. There was, however, a significant difference between the responses of male and female chemists, with almost half of female chemists on second or subsequent contracts reporting that they were now less intent on a research science career.

This seems to indicate that respondents' ambitions for careers as research scientists waned after their first contracts, and this was more noticeable for chemists, and female chemists in particular. There may be many reasons why working as a postdoctoral researcher for more than one contract seemed to make female chemists become less inclined to want to follow a research career. It could be that the reality of the difficulty of gaining a permanent academic post becomes more apparent, the cultural issues identified in the PhD study may come to dominate, or that lack of information about research careers in industry, reported by many postdoctoral researchers, results in their failure to explore this option. The apparent alternative is to give up research completely. Reasons why female physicists were not affected to the same extent are unclear; it may be related to the significantly smaller proportion of female physicists, or that the smaller core of

female physicists were more committed to careers as research physicists than their chemistry counterparts.

Despite this, almost two-thirds of all groups of respondents then selected ‘Academic on a permanent contract’ as what they were most likely to be doing in 6-10 years' time. In both physics and chemistry, there were similar proportions of both females and males on their first contracts who selected this. However, in chemistry, comparing respondents on their first and those on second and subsequent contracts, the proportion of females who selected ‘Academic on a permanent contract’ fell dramatically, but the proportion of males stayed more or less the same. Correspondingly, the proportion of females who selected ‘Scientist: industry or commerce’ almost doubled.

The picture for physics was very different, with the proportion of females choosing ‘Academic on a permanent contract’ staying almost the same between first and second/subsequent contracts, and that of males actually rising.

Nevertheless, in both chemistry and physics, men were statistically significantly more likely than women to see themselves as an academic in 6-10 years’ time once they moved on from their first postdoctoral research contract. Alongside this, almost all respondents rated their awareness of career opportunities within academia as at least adequate but only just over half of respondents rated their awareness of career opportunities outside academia as adequate or better.

The bulk of those who had received advice about careers had received it from their PhD supervisors or PI/Group Leaders. This might suggest again that the majority of respondents were focused on an academic path and consequently did not feel the need to take much advice, or that the advice they received was to pursue an academic career at the expense of everything else. Better careers advice is needed for all postdoctoral researchers so that individuals have a realistic view of the likelihood of gaining a permanent position and of research opportunities outside academia.

In terms of departmental experiences, the overriding message was that postdoctoral researchers' knowledge and experiences seemed to vary, even within the same department. There was confusion among the respondents from virtually all departments that had reasonable numbers of individuals participating in the survey as to exactly what policies were in place, especially with regard to issues such as appraisal, induction, mentoring, flexible working, representation and teaching. Some departments were better at communicating than others but the survey data suggested that even the best need to do more. The gender differences in appraisal and induction were particularly striking.

Overall, half the respondents reported feeling more like staff members than students. However, there were statistically significant differences between chemists and physicists, with physicists feeling more like staff than chemists. There were also statistically significant differences between male and female chemists, with male chemists feeling more like staff than female chemists. Only four out of 10

postdoctoral researchers believed that they were well regarded in their departments.

The way in which postdoctoral researchers were regarded and treated from department to department and from research group to research group varied, leading to the conclusion that much work needs to be done in communicating and applying an institution's human resource policies to postdoctoral researchers. Despite work that has already been done nationally and locally, in particular on developing training for research students and staff, the evidence here from the chemistry and physics postdoctoral research communities is that a great deal remains to be done. Work needs to be done on supporting the development of postdoctoral researchers through better induction and appraisal, through more mentoring opportunities and through ensuring that researchers do access appropriate training and careers advice. More challenging is the pressing need to change the culture of all departments so that researchers are valued by all staff, and so that the researchers themselves feel like valued employees who will take responsibility for their own personal development.

CONCLUSION

In conclusion, the data do raise concerns about the effect of undertaking postdoctoral research, in particular, on female chemists' ambitions to remain within the academic environment. The data suggest that undertaking postdoctoral research for a shorter period of time has little effect on long-term career ambitions but that undertaking postdoctoral research for more than one contract causes women chemists, in particular, to become disinclined towards a research career. It may be that females are simply more realistic about their chances of achieving a permanent academic post, as men are statistically significantly more likely to see themselves as an academic in the longer term in both chemistry and physics.

It would be interesting to know how strong the link is between stated career intentions and career outcomes but there are no comprehensive data on the ultimate careers destination of postdoctoral researchers in chemistry and physics.

The data also highlight some worrying issues for postdoctoral researchers in both chemistry and physics and for both males and females. Appraisal, induction and mentoring are still not commonplace in many departments and less than half of postdoctoral researchers actually feel valued within their department. It is clear that more needs to be done to improve the experience of PDRs in physics and chemistry, regardless of gender or discipline.

Overall, more differences were found between chemists and physicists than between the genders, confirming important cultural differences between the disciplines. Where gender differences were found, they were generally greater between male and female chemists than between male and female physicists. However, the gender differences were less than those found in previous RSC studies of PhD chemists. This finding is not surprising as those female PhD chemists less committed to academic research are unlikely to have gone on to work as PDRs

meaning that the motivations and attitudes of male and female PDR chemists will be more similar than those of male and female PhD chemists. Work needs to be done to ensure that the gender differences in both chemistry and physics are monitored and the issues that have been identified in this study are addressed.

ACKNOWLEDGEMENTS
Support is gratefully acknowledged to the UK Resource Centre for Women in SET (UKRC) Innovative and Collaborative Grants Scheme.

ENDNOTES

[1] The Higher Education Statistics Agency (HESA) is the official agency for the collection, analysis and dissemination of quantitative information about higher education in the United Kingdom. HESA collects data from all publicly funded higher education institutions (HEIs) in the UK as well as a small number of private providers

[2] The A–level, or Advanced Level General Certificate of Education, is a UK-based educational qualification, normally studied over a two year period, post-16 (the statutory school leaving age). A-levels are recognised, in particular, as the standard for assessing the suitability of applicants for entry to academic courses in Higher Education Institutions.

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