WOMEN IN SCIENCE AND ENGINEERING RESEARCH PROJECT

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The views expressed in this report are those of the researcher and do not necessarily represent those of the Scottish Government or Scottish Ministers.
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1 EXECUTIVE SUMMARY

Background

1.1 A literature review and a series of interviews were conducted to explore the potential social and economic impacts of not retaining women in science and engineering (thereafter referred to as women in science). This report provides a range of information about the under-representation of women in science. The patterns of under-representation are identified, and the suggested causes of this under-representation discussed. Policies and initiatives aimed at tackling these problems are then examined, and any evaluation of their impacts highlighted and discussed. Results from interviews conducted to illustrate these points further are analysed. Finally, the potential economic impacts of this under-representation are identified and discussed.

1.2 The research was conducted by the Office of the Chief Researcher between June and August 2010.

Literature review

1.3 Various different definitions of science, engineering and technology (SET) have been used by different authors. The combination of subjects included within SET can have a significant effect on the apparent gender ratio. For instance, the inclusion of nursing within a definition of SET can significantly change the overall gender ratio. The subject classification used for a definition of SET should therefore be carefully considered as it can obscure some of the patterns between individual areas of science.

1.4 There is a very limited body of research concerning women and science in Scotland. There is a wider body of literature concerning the situation in the UK and other countries, examining various aspects of the patterns of under-representation, the causes of this, and the initiatives and policies that have aimed to tackle the problems.

1.5 Women are under-represented in science at all levels. Patterns of horizontal and vertical segregation can be observed, with women concentrated in particular subjects within science and at lower grades within all sciences. There has been only limited improvement in these patterns over time. At UK level in 2009, women made up 42.4% of GCE A Level students in STEM subjects, 33.5% of higher education students in SET disciplines, 18.5% of SET employees and 8.0% of professors in SET subjects (UKRC, 2009, p1-4). In Scotland, 39.0% of STEM graduates in 2009 were female (HESA, 1999-2009). It is estimated that at any point in time, 50,000 female SET graduates in the UK are economically inactive.

1.6 A range of explanations have been suggested for the under-representation of women in science. Factors within schools and universities have been suggested, including teaching and learning methods, and attitudes of colleagues. Scientific cultures within universities and the workplace have also been key areas of concern. Finally, issues within the workplace, such as
flexible working, expectations of employees, and isolation have also been presented as causal factors. The literature suggests that there is no one single factor that can explain the complex patterns of under-representation.

1.7 A number of policy areas are relevant to women in science. Science policy, equalities policy and education policy all have implications for recruitment and retention of women in science, and could have differing effects on the current situation.

1.8 There are also specific initiatives and policies aimed at women in science. These span a range of areas, including education, universities and the scientific workplace. These interventions variously try to encourage women into science, to support those already there, and to change the culture within SET to make it more attractive to women. The actions of these individual policies are mapped later in this report in the policy and intervention map. This demonstrates the complex nature of the intended actions of these initiatives.

1.9 There is little literature evaluating the impact of these initiatives in detail, the main work in this area being that by Phipps (2008). The data needed to evaluate the impact of initiatives is also not routinely collected. It is therefore difficult to make definitive conclusions about the impact of different initiatives, or to make specific recommendations as to which policies are effective.

1.10 There is very little literature measuring the economic impact of the loss of women in science. The UK Resource Centre for Women in Science, Engineering and Technology (UKRC) has produced one estimate which measures some of the potential economic impacts but does not provide a complete picture of the total effect on the economy. This estimate was the only estimate of cost to the UK economy found in any of the literature. No estimates of the impact on the Scottish economy were found.

1.11 There is also no easily identifiable work that sets out a framework for measuring the impact of loss of women in science, or that states the data or parameters needed to make a full assessment. Due to this lack of literature, a series of model parameters and potential effects on the economy were developed from the literature on women in science. These effects are illustrated in an economic impact map later in this report which shows the various channels whereby the under-representation of women in science could affect the economy.

Interviews

1.12 Ten potential participants from science and engineering backgrounds were invited to be interviewed. Six semi-structured interviews were conducted to explore some of these themes in more detail. Several points of interest were identified from the literature review and a series of interview themes and questions developed. The key findings from the interviews are highlighted below.
1.13 Experience of science in school emerged as an important influence on future career choice for most participants. This indicates that school level experience was important in the initial decision to pursue a career in science. The importance of school level experience is reinforced by the HESA data (1999-2009) which highlights the clear gender division in subject selection in the transition from school to higher education.

1.14 Participants indicated that workplace cultures were a significant factor for them in terms of career choices and progression. Most participants were keen to highlight positive aspects of their experiences with workplace cultures. However, potentially negative aspects, including isolation and implicit and outright negative attitudes were also highlighted by all participants, even where they described their experience overall as positive. Significant negative factors and experiences therefore emerged, even where overall experiences were stated to be positive.

1.15 The difficulties of establishing a work life balance in SET careers were discussed, as were the problems of access to flexible working arrangements within SET employment. The need to work long hours in academia was highlighted by many participants. This was an experience common to all academics but could have differential impact on women’s careers. Experiences of work life balance in industry were more mixed, but also pointed to expectations of long working hours. There was a lack of obvious structures to facilitate access to flexible working, and such arrangements usually depended on personal connections. This could lead to uneven access to flexible working.

1.16 All participants were aware of initiatives for women in science. Their experiences of the initiatives varied, with some participants reporting very beneficial results whilst others had less positive experiences. Nevertheless, all were in favour of initiatives to improve the situation for women in science, and thought that such work should be continued. The need for initiatives to be able to withstand changes in levels of commitment from participating organisations was also highlighted.

1.17 Participants were unaware of or sceptical about the impact of Equality Duties within science. Those participants who were aware of the existence of Equality Duties felt that they had so far had little practical effect on improving the situation for women in science.

1.18 Few Scotland specific factors were highlighted in relation to most of the interview themes. The most commonly mentioned Scotland specific factors were initiatives such as the Scottish Resource Centre for Women in Science, Engineering and Technology that operates solely within Scotland. High profile female scientists within Scotland were also mentioned by many of the participants as positive role models who could influence others.
Conclusion

1.19 The problem of under-representation of women in science is multi-dimensional, encompassing a range of different issues. Policies and initiatives aimed at tackling the problem thus need to act on diverse areas in order to improve the situation.
2 INTRODUCTION AND PURPOSE OF THE PROJECT

Origins of the project

2.1 A Women in Science and Engineering workshop was held at the Royal Society of Edinburgh on 19th February 2010. A follow-up meeting was held between Professor Anne Glover, Chief Scientific Adviser for Scotland and Professor Alice Brown, University of Edinburgh. At this meeting it was proposed that the Office of Chief Researcher conduct some research on the economic impact of not retaining women in science. This was further discussed at a meeting between Professor Glover and Dr. Gill Clark and Dr. Vivian Leacock on 13 April 2010, where it was agreed that an outline proposal for research would be developed.

Background

2.2 Science is considered vital to Scotland’s future. It is considered a foundation in the delivery of the Scottish Government’s purpose, to

“focus Government and public services on creating a more successful country, with opportunities for all of Scotland to flourish, through increasing sustainable economic growth” (Scottish Government, http://www.scotland.gov.uk/About/scotPerforms/purposes, accessed 10th August 2010).

2.3 To enable maximum benefit from science, full exploitation of scientific expertise and resources is desirable. Evidence suggests that women are lost at key transition points. In 2007-2008 women made up 33% of higher education students in science, engineering and technology (SET) disciplines in the UK. In the same period, 70% of women graduates in SET disciplines did not work in SET careers (UKRC, http://theukrc.org/resources/key-facts-and-figures/leaky-pipeline, accessed 8th June 2010). In Scotland, in 2008-9, women made up 82.4% of students studying allied medicine (meaning subjects allied to medicine), 65.6% of those studying biological sciences, 43.1% of those studying physical sciences and 14.5% of those studying engineering (HESA, 1999-2009). Preventing the loss, therefore, of qualified and skilled women from science and engineering careers presents a considerable challenge.

Aim and objectives of the research

2.4 The aim of this project is to investigate the potential social and economic impacts of not retaining women in science.
2.5 The objectives are:

- To identify and map the key initiatives and their stated outcomes, where available, that have attempted to address the institutional structures and systems that may lead to under-representation of women in science.

- To identify and map the reasons, through examining the existing literature, why women leave science at all stages of the career continuum (the ‘leaky pipe’).

- To identify economic models that might be used to explore the potential economic impact of losing women from science careers.

2.6 The research questions are:

- What are the patterns of women’s participation in SET careers in Scotland?

- What can be done to limit/reduce the attrition rates for women in SET careers?

- What are the potential consequences for Scotland’s economy of losing women from SET careers?

Timeframe

2.7 The project was undertaken over a total of twelve weeks from 7th June to 27th August. The short time frame of the project, therefore, provided some constraints on the type and scope of research that could be undertaken.

2.8 With the timeframe in mind, it was decided that a literature review would be conducted, and a series of interviews used to investigate themes indicated by the literature review. It was not possible to conduct a systematic review or a wider interview or survey programme.

2.9 The literature review was also used to develop a policy intervention map, and an overview of the economic impact of the loss of women in science.
3 METHODOLOGY

3.1 This section explains the methodology that was employed in order to achieve the project’s aims and objectives. The research was qualitative and involved conducting a literature review and in depth semi structured interviews with female scientists and engineers. In depth interviews were chosen as the most appropriate method to allow women to tell their experiences, stories and perceptions of their careers in science.

Literature Review

3.2 A review of the literature was conducted using various online databases and search engines such as Google Scholar, Copac, and Google to identify relevant academic, policy and grey literature on women in science.

3.3 Searches were made in the first instance for research concerning the situation in Scotland in order to identify the existing evidence of the problems in Scotland, and also to identify any Scottish specific aspects to the situation. Further searches were then conducted to identify a wider range of literature concerning the United Kingdom and appropriate examples from other countries.

3.4 The literature identified originated from several main areas. Research produced by organisations involved with women in science, for instance the UKRC, provided one significant source of information. Gender and Education, The International Journal of Gender, Science and Technology, and other journals in science, education and gender provided articles about women in science. Finally, several books concerning women in science were consulted.

3.5 The literature examined was then used to prepare a literature review, policy intervention map and economic impact map.

Interviews

3.6 In depth semi-structured interviews with female scientists in Scotland were conducted to expand on the key themes highlighted by the literature review and to explore any Scottish specific factors.

3.7 Ten participants were selected by contacting women who were already known to policy colleagues and researchers within the Scottish Government due to their involvement in other Scottish Government projects and their positions within science. Six of those approached agreed to participate, three declined, and one did not respond to the invitation.

3.8 Participants were drawn mainly from academia as the time frame of the project did not allow for the identification of a wider set of participants. For this reason it is important to note that the views of participants are not representative of women scientists’ experiences across all subjects and sectors of employment.
3.9 The interviews were conducted by telephone or face-to-face according to interviewee preference and practical considerations. Four interviews were conducted face to face, and two by telephone. The interviews were recorded and notes were taken. The main findings are discussed in Chapter Eight.
4 DEFINITIONS AND STATISTICS

4.1 This section discusses the statistics used to identify women’s participation in science, and identifies the patterns of under-representation of women in science, engineering and technology in Scotland and the UK.

Definitions of Science, Engineering and Technology (SET)

4.2 When evaluating the statistics and policies on women in science it is important to understand what subjects have been included within definitions of SET.

4.3 Several classifications have been used by different groups (Glover and Fielding, 1999, Scottish Executive, 2007). These definitions agree on the inclusion of some subjects, such as engineering, physical science and biological sciences, within SET. However, other subjects are more difficult to categorise. Whether various different subjects allied to medicine, in particular nursing, are included within SET is a key point of difference between different sources (Glover and Fielding, 1999, UKRC 2009, DTI, 2003, 2006).

4.4 These different subjects have significantly differing gender balances: for example, engineering is strongly male dominated whereas nursing is strongly female dominated. This gendered split in subjects studied in higher education in also evident in Scotland, and this pattern has remained the same over the past ten years. In 2008-9, women made up 82.4% of those studying allied medicine, 65.6% of those studying biological sciences, 43.1% of those studying physical sciences and 14.5% of those studying engineering (HESA, 1999-2009). In 1999-2000, female participation in the same series of subjects was 83.1%, 64.4%, 37.7% and 16.3% respectively (HESA, 1999-2009). These different subjects are also of vastly differing numerical sizes (Scottish Funding Council, 2006). The combination of subjects included within a definition of SET can therefore significantly affect the apparent gender balance in SET as a whole.

4.5 Given that there were a range of classification systems available, choices had to be made about the ones that would be used in the project. It was decided that existing statistics, with their varying classification systems, would be used where appropriate. However, where original statistics were sought the STEM subject classification list produced by the UKRC (UKRC, 2009) would be used in order to allow direct comparability with their UK wide statistics. The full UKRC subject classification is included on p.p. 47-8. The various different statistics on proportions of women in science may not show exactly the same patterns due to differences in definitions.

Cross national statistical patterns

4.6 The under-representation of women in science has been highlighted by many authors over a long time period and across different geographies. The key patterns and problems have been identified in many nations (UNU-IAD, 2005, Bebbington, 2001). These patterns are explored in detail in European
Commission research, which shows that women are in the minority in science across the EU (European Commission, 2008. It should, however, be highlighted that not all men with a SET degree progress on to employment within SET (Scottish Government, 2010, Fielding and Glover, 1999). Nevertheless, the attrition rates for men are generally significantly lower than those for women. Annual Population Survey data does not have sufficiently high numbers to allow us to examine the employment sectors to which women STEM graduates in Scotland progress later in life (ONS, April 2009 - March 2010).

4.7 Different indicators and measures have been used to measure the participation of women in SET. The data needed to assess gender segregation has not always been routinely collected (Cronin and Roger, 1999). The proportion of students studying a particular subject who are female is commonly used. Nevertheless, changes in the proportion of women studying a subject could also be influenced by a decreasing number of men studying a subject as well as an increased number of women. This would indicate a decline of interest among men for certain subjects rather than an increase in interest among women (Cronin and Roger, 1999). The analysis in this report is limited by the types of data available and most of the data used concerns proportions of women in particular subjects or fields of employment.

4.8 Various patterns of under-representation can be identified. One key pattern is horizontal segregation, where women are concentrated in particular scientific subjects (Department of Trade and Industry, 2006). Another pattern is vertical segregation, where women are under-represented in more senior levels of organisations (Glover, 2000, UKRC 2010). These patterns have been a key focus of recent literature on this topic (Larios et. al., 2009).

4.9 These patterns have remained fairly constant over the past twenty years. There has been long term improvement in rates of female involvement in sciences from the 1960s onwards (Glover and Fielding, 1999). However, this improvement has not always been consistent or significant. From 1984 to 1994, women taking science degrees as a proportion of all women taking degrees remained stable, even though the proportion that was female of those taking science subjects increased. This shows that at least some of the increase in the proportion of women taking certain subjects was due to a decline in male uptake of these subjects (Glover and Fielding, 1999). In Scotland, higher education statistics reveal that gendered patterns remain (HESA, 1999-2009).

4.10 Between 1971 and 1991, the gap between men and women’s post-SET degree employment in SET has narrowed but not closed (Bebbington, 2001). The increase in representation of women in SET has been very slow compared to changes in law and medicine (Glover, 2000). Due to small samples, Higher Education Statistics Authority and Annual Population Survey data cannot provide us with data regarding the longer term destinations of graduates in Scotland (HESA, 1999-2009 & ONS, April 2009 - March 2010).
4.11 “Time lags” have been suggested as one cause of vertical segregation. One American study identified that the proportion of physics professors who were female was in line with the recruitment of women into physics in the age groups from which most professors were drawn (Committee on Science, Engineering and Public Policy, 2007). However, they also acknowledged that this did not fully explain all vertical segregation, and in any case did not explain ongoing causes of segregation (Blackwell, in Glover, 2000).

Current situation in the UK

4.12 In 2009, girls made up 42.4% of GCE A-Level students in STEM subjects. This conceals significant differences between subjects, as women are 7.5% of all computer science students and 21.4% of all physics students (UKRC, 2009, p1).

Women made up 33.5% of all higher education students in SET disciplines. There is considerable horizontal segregation, with women making up 15.9% of technology students and 21.4% of computer science students (UKRC, 2009, p1).

Women represented 18.5% of SET employees (UKRC, 2009, p1).

Women hold 9.0% of Directorships in the UK FTSE 100 companies in SET sectors (UKRC, 2009, p1).

8.0% of all SET professors are female. Women make up less than 5% of the professorship in many subject areas including physics, mathematics, and various subsets of engineering (UKRC, 2009, p1).

UKRC estimated that at any point in time 50,000 female SET graduates are economically inactive (UKRC, 2010). Of those who re-entered the workplace after a career break, only 8,000 went back into jobs that utilised their qualifications and expertise.

Projecting these figures based on past trends in England and Wales, female and male students will be equally represented at A Level in 2058, in SET disciplines in higher education in 2069, and female SET employment will not reach parity within the 21st century (UKRC, 2009, p4).

The current situation in Scotland

4.13 In 1995-6, women accounted for 32% of university students in SET disciplines (Cronin and Roger, 1999). This rose to 37% by 2002-3, and 39% in 2008-9 (HESA, 1999-2009). There was considerable variation between disciplines in 1995-6, ranging from 14% in engineering and technology to 62% in biological sciences (Cronin and Roger, 1999). This pattern was consistent across the next decade, so that in 2008-9, 65.6% of those studying biological sciences were female compared to 14.5% studying engineering (HESA, 1999-2009).
These patterns were persistent, with three broad groups of subjects, namely engineering, physical sciences and mathematical sciences, having 60-90% male students. Biological sciences and subjects allied to medicine showed a predominance of women, with women making up over 65% and 85% of students respectively (Scottish Funding Council, 2006).

In Scotland there are 209,200 people who hold a STEM degree. Of these, 71% are male: this is higher than the overall figures for graduates in Scotland, where 50% are male (ONS, April 2009-March 2010).

Data from the Annual Population Survey for April 2009 - March 2010 gives information about the employment of STEM graduates in Scotland. The employment rate for STEM degree holders is 83.8%, which is higher than for people in Scotland with no degree (71.2%), but lower than for those with a degree in any discipline (85.5%). Within the STEM group the employment rate for women is lower (80.2%) than for men (85.3%) (ONS, April 2009-March 2010). This means that women with STEM degrees are less likely to be in employment than men with STEM degrees (ONS, April 2009-March 2010). Lack of data from Higher Education Statistics and the Annual Population Survey means that we cannot determine graduates’ career destinations and whether STEM graduates progress onto STEM related employment (ONS, April 2009-March, 2010).

According to the Scottish Resource Centre (2010), despite this difference in gendered participation rates, only 29% of female SET graduates in Scotland are working in the sector in which they are qualified, compared to 52% of male graduates (Scottish Resource Centre for Women in SET, 2010, p6).

Data on workplace participation from 2006 shows that men dominate certain industries, making up 89% of the workforce in construction, and 73% in manufacturing, whereas women make up the majority in sectors such as public administration, teaching and health, where they are 72% of the total workforce (Scottish Executive, 2007, p103). Trends in the distribution of men and women in employment show little overall change between 1996 and 2004 (Scottish Executive, 2007, p104).

Implications of these patterns

Under-representation is concerning for several reasons. The literature suggests that these concerns centre around three main themes: equalities, culture, and business and economic. The following section therefore sets out the main arguments in each theme.

Equalities

The unequal representation of women in scientific education and careers can be framed as an equality issue. This foregrounding of equality can be linked to an overall aim of fairness in liberal society. However, in recent academic debates justifications based solely on equality have become less common and concerns based on economic factors have become more commonly cited.
Some authors are concerned that justifications based on equality are being displaced by economic concerns (Phipps, 2008).

Scientific Culture

4.21 Authors have suggested that greater female involvement in science, in particular academic science, could act to change the culture of science for the better (Shiebinger, 2000). This argument emerged from various discussions from the 1970s onwards about the masculine nature of science and the practice of science (Phipps, 2008). Some argued that higher proportions of women could lead to changes in the way science was conducted. However, the extent to which science would be fundamentally changed by the involvement of more women has been questioned by some authors (Phipps, 2008). There are few investigations of this theme in the literature on the UK (Larios et. al., 2009).

Business and Economic

4.22 The idea that gender segregation is detrimental to business is also highlighted as a major concern. Businesses with more diverse staff and leadership tend to perform more positively on financial measures (UKRC, 2010). This argument has been adopted by many of the key organisations working in this field including the UKRC. The UKRC argues that companies images and respected status, for instance as an employer of choice, will be affected by whether they have a diverse workforce (UKRC, 2010). A diverse workforce will have other benefits in increasing productivity by recruiting from the whole talent pool, and profitability by being able to identify with their entire range of clients (Bagilhole, Powell and Dainty, 2008).

4.23 Costs to businesses are also highlighted. The loss of skilled and productive women from SET employment is represented as having a financial impact on business due to the costs of replacing staff and the loss of skills and expertise then experienced staff leaves (UKRC, 2010). The UKRC has also emphasised the potential costs to businesses of ignoring equalities issues or getting them wrong, highlighting the potential for high compensation settlements if equalities issues are ignored (UKRC, 2010).

4.24 Skills shortages are also cited as a reason for concern. Projections predicted that by 2010, white able bodied males would be in the minority in the labour force, meaning that companies that recruit primarily from this group would need to look more widely or risk being caught up in a skills shortage (UKRC, 2010). This could be placed in a science specific context: as the uptake of science subjects by men decreases, the problems of uptake and retention of women in science become more visible and acute leading to more concern about attracting women to SET (Glover and Fielding, 1999). Statistics from the Labour Force Survey reveal that white males make up just under half (48.3%) of all those in employment in the UK, which constitutes a larger proportion of the workforce than any other group. The statistics are not disaggregated by able and non able bodied (ONS, July-Sept 2010).
4.25 The business and economic related arguments for retaining women in SET careers have, however, been criticised by some authors as inadvertently reinforcing some existing discriminatory ideas about women (Phipps, 2008). Some authors have claimed that the recent primary focus on the economic benefits of women in science could perpetuate problems for women in science by singling them out as different from other scientists, and thus perpetuating cultures which see women as different and potentially unsuited to scientific careers (Phipps, 2008). By presenting women as the answer to a skills shortage there is also danger that they could be seen as the “last resort” and not as a normal group to recruit from (Bagilhole et. al., 2008). This would mean if skill shortages abated, this rationale for recruiting women would then disappear. An historical example of this is the employment of women to fill temporary skill shortages in engineering during World War Two. When the skill shortages no longer existed, women’s employment in engineering declined. The business case could therefore undermine the long term progress of women in science.

4.26 The business and economic argument also does not deal with some factors affecting women’s retention in science. Attempting to recruit women as a way to avoid skills problems or maximise profit can co-exist with a lack of attempts to change potentially harmful organisational cultures and workplace conditions that worked against the retention of women in science. Existing research shows that the idea of “critical mass”, whereby increasing representation of women in particular sectors leads to changes in the conditions in these sectors, does not seem to strongly improve the position of women in science (Etzkowitz et. al., 1994). For these reasons, the recent focus on the business case has been seen by some as providing an incomplete view of under-representation of women in science. All of the impacts described in this section must be taken into account if the full significance of failing to tackle under-representation of women in science is to be understood.
5 LITERATURE REVIEW: EXPLANATIONS FOR PATTERNS OF UNDER-REPRESENTATION

5.1 A wide range of reasons have been suggested to account for under-representation. This review outlines some of the explanations that have been posited, including factors in relation to experiences in schools, universities, academia, work cultures and employment structures. The factors are discussed below in the chronological order that women are likely to experience them in their careers to illustrate the cumulative nature of these problems.

Science in schools

5.2 There is a wide literature on female participation in science at all levels of schooling. Schooling and early life experiences emerge as key areas in which ideas about science are formed (EU report, Sanders 2005, Roger and Duffield, 2000). This is also evident in the gendered pattern of subject uptake at university level raising questions as to the potential importance of the school curriculum and careers guidance in schools and their potential role in motivating male and female children to study certain subjects (HESA, 1999-2009) (see the position of schools in the ‘policy intervention map’ later). Research has examined these patterns and looked for their causes, for instance concerning the role of the media via children’s TV programmes (UKRC, 2008). Schooling thus emerges as a key area to which policy should be directed (Bagilhole et. al., 2008). Detail about the influence of education and the history and evaluation of policy in education can be found in Phipps (2008).

5.3 It is also instructive to consider the literature that identifies particular Scottish dimensions to the situation in education. There is a small literature on gender and science education in Scotland. For example, work on the comparatively high uptake of physics in Scottish schools highlights points at which intervention could be targeted in order to improve female participation in physics (Reid, 2003). The points at which male and female pupils lost interest in physics differed, and early secondary school was of particular importance to girls (Larios et. al., 2009). Other works discuss female engagement with technology in Scottish schools (Murdoch, 1997).

Universities

5.4 These problems continue at university level. Research cited by Cronin, Foster and Lister found that male lecturers tended to treat women differently than men in terms of questions asked, time allowed to respond to questions, interruptions, response to questions, and various other behaviours which, although small individually, could add up to significant differences in classroom experience (Cronin, Foster and Lister, 1999). Research from the United States also reinforced this, indicating the subtle and cumulative nature of these differences in treatment (Sanders, 2005). Cronin and Roger also identified negative attitudes from male peers and lecturers as a factor in
dissuading women from persisting in SET (Cronin and Roger, 1999). UKRC research on the experiences of women in built environment courses in higher education found that although the majority expressed positive opinions, 25% reported feeling isolated in all male settings and feeling a need to “prove themselves” in everyday situations (UKRC, 2008, p7).

5.5 Teaching and learning methods in universities can also have an impact (Cronin and Roger, 1999). Narrowness of course materials and male focussed examples had been highlighted from the 1970s onwards as problems for women in science (Blickenstaff, 2005, Cronin and Roger, 1999). These can vary between subjects, with some subjects having more of this type of problem. However, academia has often tended to locate the problem outside its boundaries, blaming wider employment issues or pre-university education for the problems faced by women in SET (Bagilhole et. al., 2008).

**Scientific cultures in university and the workplace**

5.6 Scientific culture also emerges as a key area of concern and study. Many pieces of research found that women find the culture of SET departments off-putting, and that this has significant impact on their career aspirations and choices (Cronin, Foster and Lister, 1999, Sappleton and Takruri-Rizk, 2008, Blickenstaff, 2005). Negative stereotypes such as the “geek” stereotype for computing were also posited as reasons why women were deterred from pursuing certain subjects (Sanders, 2005). Although these factors are not cited directly as reasons why women may choose to leave science, and in fact may be seen to make women more determined to persevere, the cumulative effects of negative, rude or uninviting cultures can be seen to undermine desires to persist in SET (Cronin, Foster and Lister, 1999).

5.7 Negative workplace cultures have been seen as a reason for the under-representation of women in SET careers. Much of the research concerns academia (Larios et. al., 2009). The hegemonic masculine culture of SET workplaces can help to explain why there has been so little progress in the impact of equalities policy despite the high uptake of these policies in SET organisations (Sappleton and Takruri-Rizk, 2008). These cultures are able to accommodate equal opportunities but are not able to implement them (Sappleton and Takruri-Rizk, 2008).

5.8 Research has also highlighted sexism in the workplace. Bagilhole et. al. conclude that in SET, women are regarded as women first and professionals second (Bagilhole et. al., 2008). This was displayed by both men and women in terms of language, humour, style and appearance and usually worked to undermine women’s professional status. Other research discusses the subtle and non-visible nature of this discrimination (Sappleton and Takruri-Rizk, 2008). Women tended to deal with such challenges by changing their behaviour and managing their appearance, as challenging the culture risked further alienation (Bagilhole et. al., 2008). Other research has pointed to the effects of all male cultures on women’s participation, and on the exclusion from informal networks occurring in some SET organisations (Sappleton and Takruri-Rizk, 2008).
5.9 It has been suggested that women adapt to masculine workplace cultures and become “acculturated” (Larios et. al., 2009). This leads them to deny the influence of gender in the workplace (Bagilhole et. al., 2008). This means that increases in the number of women in certain areas will not necessarily lead to cultural change as coping strategies co-opt women into existing cultures, and these approaches are often individualistic (Bagilhole et. al., 2008).

5.10 While the extent to which cultures could be deliberately contested is under debate, Bagilhole et. al. concluded that without significant change scientific workplace cultures would remain problematic (Bagilhole et. al., 2008). These workplace cultures have not changed much over the past twenty years (Bagilhole et. al., 2008). Given the gendered nature of many workplace cultures in SET it has been suggested by some that encouraging women to enter these fields is irresponsible (Bagilhole et. al., 2008).

Science in academia from the position of an employee

5.11 Research on science in academia provides some particular reasons why women leave this type of SET career. Geographical mobility can be of particular concern in academia as there can be expectations that in order to progress, researchers should be mobile. In couples where both partners are pursuing a career in science it can be difficult to find job opportunities in the same area for both people (Bebbington, 2001, Larios et. al., 2009). Evidence from the United States shows that female scientists were more likely to be married to a male scientist than vice versa and the age difference in couples was often such that the male partner was older and more senior. For this reason the mobility of female scientists was disproportionately affected (Wolfinger et. al., 2008).

5.12 Some studies show the impact of child-bearing and career breaks on women in science within academia. The need for an ongoing research record can disadvantage those who take career breaks for whatever reason, disadvantaging women with childcare responsibilities. The constraints of family responsibilities and childcare could also impact on career mobility (Larios et. al., 2009). Senior female academics were also more likely to be childless than their male colleagues.

5.13 The problem of returning to SET after a career break is highlighted by research. The pace of change in SET has been identified as a cause of skills becoming rapidly obsolete, meaning that those who take a career break find it difficult to re-enter the sector at all, and also difficult to re-enter at the level which they left.

5.14 It was also found that women were often working below their qualification level (Glover and Fielding, 1999). This pattern can be found even at the start of women’s careers, and does not emerge solely among women returning to science. Under-utilisation of skills was thus found to be a significant concern within SET.
Employees and promotion

5.15 Issues related to ideas about the desired characteristics and behaviours of the ideal employee have also been suggested as a cause of under-representation of women in scientific careers. The ideal of the perfect scientist often includes aspects and behaviours which are generally coded as male, setting up a fundamental inconsistency between femininity and science (Bagilhole et. al., 2008, Ellis, 2003). The business based argument can also put pressure on women to fit into existing cultural models rather than challenge existing assumptions (Bagilhole et. al, 2008). Deviation from a groups’ collective gender orientation and accepted behaviours could affect the way an individual was seen to “fit in” to a team, and affect their progression in their career (Larios et. al., 2009).

5.16 The perception of the ideal SET employee as male can put additional pressures on women. Several studies have identified reluctance among many female scientists to present themselves as pushy or overly masculine (Sappleton and Takruri-Rizk, 2008). The difficulties of overcoming these problems mean that women often construct particular professional personas which can inadvertently hamper their career progression (Sappleton and Takruri-Rizk, 2008).

5.17 A lack of senior female employees in various areas of SET employment has been suggested as a cause of under-representation. The lack of role models in senior posts in some industries, in this case construction, was posited as a reason for poor female participation in these areas (UKRC 2010, UKRC, 2006). Evidence on the influence of role models can be ambivalent. Studies from the US found that the mentors could be of influence in encouraging women to pursue certain careers, but found little evidence for the influence of role models (Sanders, 2005). The question of role models can also be investigated in relation to issues of the “perfect employee”. Where women who have succeeded in science have done so by conforming to the image of the stereotypical male scientist then the role models available to women in science may be unappealing or actively off-putting (Blickenstaff, 2005).

5.18 Networking has been identified as a means of overcoming these problems and encouraging women in science, but research has identified that women are often excluded from existing networks as many networking activities are based on activities traditionally thought to be male (Bagilhole et. al., 2008). Involvement with networking or policies aimed at women could also be construed negatively by other colleagues (Etzkowitz et. al., 2000). This can lead to further segregation of women.

Flexible working and work-life balance

5.19 The availability of part-time working has been highlighted as a concern. Flexible working and part-time working were often not easily accessible in SET (UKRC, 2010, Sappleton and Takruri-Rizk, 2008). This has particular implications for women with family and childcare responsibilities (UKRC, 2010).
5.20 Part-time working may be regarded as demonstrating less overall commitment to the organisation, and companies often tend to invest less in training and development for part-time staff (Sappleton and Takruri-Rizk, 2008). This association of women with part-time work may make them seem less like the “ideal” flexible worker, and thus hamper their efforts to progress in the organisation (Sappleton and Takruri-Rizk, 2008).

5.21 The need or perceived need to follow “male” working patterns in order to succeed was also cited as a cause of the under-representation of women in some sectors, for instance construction (UKRC, 2008). The dominant workplace culture of long hours and total availability as markers of commitment and promotion potential was once again of particular detriment to women with domestic and family responsibilities (Bagilhole et. al., 2008).
6 POLICIES AND INITIATIVES

6.1 The statistics and patterns described above have led to various initiatives and policies that aim to combat the under-representation of women in science. The issues relating to women in science link into a wide range of policy areas. This section therefore sets out the wider policy context, and then details the specific policies aimed at women in science, examining assumptions upon which they are based, the actions they have taken, and evaluations of their impact.

Wider policy context

Science policy

6.2 Science policy more widely has direct relevance to the issue of women in science. Recruitment and retention of workers within science more generally has been a key area of policy concern for the Scottish Government. For the sake of brevity it has been decided to limit the discussion to current policy programmes only.

6.3 The main recent policy programme of relevance to this project is the Science for Scotland framework. The framework, published in 2008, sets out the main tasks to be achieved and policies needed to realise the intended role of science in Scotland’s economy and society. These include encouraging participation in formal and informal science education at various levels, making the science curriculum more interesting and relevant, encouraging research, and aims relating to scientific culture and science in society.

6.4 Many of these can be seen to have direct relevance to women in science, for instance those relating to encouraging pupils to pursue careers in science and varied training opportunities. The aims of the framework do not contain any specific gendered aspects, although the programme has been equality impact assessed and monitored on the six equality strands (Scottish Government, 2008a). In this way, the main Science for Scotland framework has direct relevance for any policy on women in science, as overall attempts to increase participation in science could interact with the current situation for women in science, and existing policies aimed at the recruitment and retention of women.

Equalities policy

6.5 Equalities policy is also of relevance here. Decisions on a large proportion of equalities policy and employment policies are beyond the remit allowed to the Scottish Government, and policy here is often determined by EU level policy, implemented via UK law (Scottish Executive, 2007). There are a number of pieces of legislation and policies relating to equality, the most recent and significant being the Equality Act 2006 which introduced the Equalities Duties including the Gender Equality Duty (The Public & General Acts, 2006).
6.6 Equalities issues are a significant area of interest for the Scottish Government. Currently, the main efforts are towards the two ministerial priorities, tackling occupational segregation and tackling violence against women (Scottish Government, 2010). The efforts towards tackling occupational segregation are of direct relevance to the issue of women in science, as the under-representation of women in science is a key example of occupational segregation. The various initiatives aimed at reducing horizontal and vertical segregation could thus be seen to be aiding more direct efforts to increase female participation in science. Information gathering as part of the priority on occupational segregation can also be seen to help identify more clearly the nature of the situation for women in science in Scotland. The impact of equalities legislation on science is unclear. In some research, equalities legislation was found to have little impact on the work situation of female academics (Larios et. al., 2009).

Education policy

6.7 Education policy is also relevant. The main recent development is the Curriculum for Excellence which gives more flexibility in tailoring education to the needs of specific learners. Other education policies aimed at equality are also in place at various levels. For example, the Scottish Government in particular has highlighted the differential uptake of science subjects by men and women as a key problem, and has argued that services should be equally available to all (Scottish Government, 2008b).

Women in Science: Specific Initiatives and Policies

Underlying assumptions and theories

6.8 Policies and interventions designed to increase female participation in SET can be grouped into various categories according to the different ideas about both women and science that underpin them.

6.9 Cronin and Roger divide them into initiatives aimed at getting women into science, those aimed at supporting women already studying or pursuing a career in SET, and those that aim to change SET teaching and cultures to make it more inclusive (Cronin and Roger, 1999). These three practical positions have significantly differing approaches to women and science. Different policies undertaken by the Scottish Government can be seen to fit into all three of these frameworks. Two particular assumptions, critical mass and the deficit model, have attracted specific attention and criticism.

Critical Mass

6.10 The idea of ‘critical mass’, also referred to as a “pipeline” approach, underpins many policies. This posits that when groups enter new fields in which they are minorities, they initially need outside influence to sustain themselves, but as their numbers grow a point is reached at which the group is able to sustain themselves. This point is usually defined as one of strong minority that is about 15% (Etzkowitz et. al., 1994).
6.11 Some research examining uptake of technology subjects in universities in the US found that critical mass had significant influence over the retention of women (Sanders, 2005). Cronin and Roger identified that critical mass was a necessary step for increasing female participation in Scottish higher education, but on its own it was insufficient to make a significant impact (Cronin and Roger, 1999). Modest increases in the number of women in the scientific workplace, when paired with little or no change in the workplace culture produces a paradox of critical mass (Etzkowitz et al., 1994). Attempts to increase the number of women entering scientific careers are thus not sufficient to solve the problems of vertical segregation.

The Deficit Model

6.12 Another key approach that appears in many policy discussions is the “deficit approach” (Phipps, 2008). This term is used by critics to describe any intervention or explanation for difference that implicitly or explicitly assumes a deficit on the part of women (Phipps, 2008). By locating the needed changes with women, these initiatives, however well intended, are seen to reinforce the idea that women are at fault and need to transform their “undesirable” characteristics. This hinders attempts to transform science and scientific cultures themselves. The deficit model has come under scrutiny in more recent discussions from a range of authors (Phipps, 2008, Athena Project, 2001, Athena Forum, 2009), but remains an implicit if unconscious principle in some ongoing programmes, for example, Women into Science and Engineering (WISE).

Specific initiatives and policies

6.13 There are numerous initiatives and policies aimed at increasing female participation in science. These act at various different levels and on different areas, as the policy and initiatives map on p28 aims to show. The map puts the aim of increasing female participation in SET at the centre, and shows the various different areas, such as education, through which this could be achieved. The different types of initiatives that have aimed to affect these different areas are also shown, with arrows denoting the areas they aim to influence. The map shows that policies acting on all these areas are necessary in order to have the biggest impact on patterns of under representation.

6.14 Evaluating the impact of policies is important in gauging their effectiveness. Evaluating policy overall is difficult. The European Commission has investigated the impact of national policies for women in science in a range of countries. The report found that countries with specific high level and governmental policies to try to improve the situation for women in science actually tended to have lower proportions of women in science. They concluded that this was due to a range of factors within the science sector of these countries which were linked to the level of development of the sector and its economic importance. This indicated that higher levels of science and technology arising out of economic development would actually be expected
to worsen the situation for women in science. National level policies could therefore be seen as a response to this situation, and it was thus difficult to assess the impact of policies (European Commission, 2008). There is little detailed work evaluating the impact of different policies on the experiences of women in science in the UK (Cronin and Roger, 1999). The main detailed work on this topic is that by Phipps (2008). Other authors often assume success for schemes without exploring whether their interventions were the cause of the changes observed (see for instance WISE, 2010). This lack of critical analysis introduces risk into policy making as gender relevance is either over or under stated in relation to all other explanatory factors (Phipps, 2008).

6.15 One of the problems hindering any comprehensive review of the various initiatives is a lack of good quality data on the impact of policies (Phipps, 2008). More recently there has been greater focus on evaluative data. The UKRC holds a record of the numbers of women with whom it had engaged in its work, and also statistics on the outcomes for returners in its programmes (UKRC, 2010).

6.16 Evaluating the impacts of each individual policy would be extremely time consuming, and as pointed out already, very difficult, and is also beyond the scope of this project. This report therefore examines the main synthesis of policy evaluation, namely the work of Phipps, 2008, and combines this with other evaluation data where available.

6.17 Work that examines the overall impact of initiatives and policies aimed at promoting the cause of women in science has provided a mixed verdict on the success of policies. Some texts have assumed a positive impact for various policies, citing increases in the proportions of women pursuing certain courses as evidence for different policies' success (e.g. WISE, 2010).

6.18 Others have presented a more varied picture. Phipps (2008) points to the limited successes and impact of initiatives in general, but tempers this with statements acknowledging the wide range of challenges facing these initiatives which severely limited their ability to change the situation, and acknowledges their role in bringing this issue into public debate.

6.19 Some authors posit that the trends in participation might have occurred without intervention. Comparison between the United Kingdom, which implemented a range of initiatives to encourage women into scientific careers, and France, where there was little or no public rhetoric and debate about this issue shows that France experienced a similar increase in the proportion of women in engineering compared to the UK (Glover and Fielding, 1999).
General initiatives

United Kingdom Resource Centre for Women in Science, Engineering and Technology (UKRC)

6.20 The UKRC is funded by the Department for Business, Innovation and Skills. It was established in 2004 in response to recommendations made by SET Fair (Greenfield, 2002). It is based at Bradford, and has centres at various locations across the UK, including a Scottish centre at Napier University (UKRC, 2010). The Scottish centre provides a range of services and produces a range of publications. Phipps claims the establishment of the UKRC represented the high point of an alliance between economic interests and women’s issues (Phipps, 2008).

6.21 The overall aim of the UKRC is that ‘By 2030 we will have an environment in UK SET employment, research and policy making, in which women contribute to, participate in and share the benefit equally to their male counterparts’. In order to achieve this, the UKRC provides a range of services and undertakes a range of projects. The wide ranging nature of its reach is illustrated in the policy and intervention map. It provides a wide variety of types of guidance for organisations and business on best practice in employment. They provide services for women in SET, including training, mentoring, support, careers advice and other services. The UKRC also funds other projects such as the Athena SWAN charter and acts as a portal to other organisations. The UKRC also supports a wide range of policy proposals (http://theukrc.org/influencing-policy). Details of the activities of the Scottish Branch of the UKRC can be found at their website (Scottish Resource Centre, http://www.napier.ac.uk/randkt/rktcentres/src/Pages/default.aspx).

6.22 The UKRC has set targets for themselves by which they can measure their progress, and their website and publications contain measures of the success of policies (UKRC, 2010). Research by Bagilhole et. al. on behalf of the UKRC identified the UKRC as a factor encouraging positive change in university cultures (Bagilhole et. al., 2008). Nevertheless, the project is so recent that it is too early to evaluate the long term impact of its various schemes and initiatives.

Education

6.23 Many of these interventions and initiatives have been short lived and specific to particular areas. There were two main waves of activity, one in the 1970s and then in the 1990s (Phipps, 2008). Some initiatives are still active, for instance Women Into Science and Engineering. Most of these initiatives have no detailed evaluation process that tracked the impacts of these programmes over the long term.

Women into Science, Engineering and Construction (WISE)

6.24 One of the most prominent and long running initiatives, WISE was founded in 1984 with the aim of encouraging understanding of science among young girls
and women and to promote choosing it as a career. They provide a range of different services and initiatives in order to achieve this aim, and engage with other organisations that provide such services. This includes resources for girls, teachers and parents (http://www.wisecampaign.org.uk/).

6.25 There is some limited work evaluating the impact of WISE policies in the short term. This indicates that although school visits by WISE did have a positive effect on girls’ opinions of science this was not translated into long term change in their career ambitions (Phipps, 2008). Other research claimed the campaign had an impact in prompting other projects and in raising awareness (Evetts, 1996). However, others were more critical, claiming that WISE inadvertently limited the ways in which girls and women could discuss the challenges they faced (Henwood, 1996). The long term impact of WISE programmes can only be measured using the proportions of engineering students and engineers who are female (WISE, 2010). There is no detailed research evaluating whether their actions and policies have produced the impact, or whether other factors were at play. For this reason, it is difficult to definitely conclude that their policies have been the decisive or contributory factor in encouraging female participation in scientific careers (Phipps, 2008).

Universities

6.26 Some initiatives have aimed at university level, aiming to increase retention of students throughout university, as well as encourage networking and mutual support among students. Many of these groups and projects operated within individual universities. Some are still active.

Interconnect

6.27 This organisation, set up in 2009, helps to encourage and facilitate networking for women studying science, engineering, technology and the built environment within Scotland. The organisation offers resources and grants for students to set up groups at their college or university, and also helps link up different groups. They also offer career development services and access to information about news and events (Interconnect, http://www.interconnect.org.uk/, accessed 12th August 2010). The organisation is very recent and thus there is currently no evaluation of its impact.

Academia

6.28 Other initiatives have aimed to improve the situation for women in academia. Many initiatives were not very well documented or publicised, (Cronin and Roger, 1999). They are often locally based, organised by women themselves, and not in receipt of official funding (Cronin and Roger, 1999). The number and range of programmes makes identification, description and comparison of these initiatives difficult. Some recent and current initiatives in academia are listed below.

Athena Project/Athena Forum
6.29 This project emerged from the recommendations made by the Rising Tide report, 1994, and the Promoting SET for Women Unit set up in 1995. The project ran from 1999 to 2008 and was run by women in SET. 80 UK universities took part in one or more of the schemes run by the project.

6.30 The Athena project provided a variety of services, including advice to university departments, award and prizes based on identified examples of “best practice”, support for women via networking, professional development and mentoring, and attempts to change institutional and organisational cultures.

6.31 The Athena forum continues some of the work undertaken by the Athena project. The project also led to the creation of the Athena/SWAN charter, to which university departments sign up and receive support in advancing the cause of women in science.

6.32 There is no work formally evaluating the impact of the Athena Project or its successor projects. Research by Bagilhole et. al. on behalf of the UKRC identified the Athena Project as a source of positive change in university cultures. This programme has also been assessed according to the number of university departments that have received awards at various levels, or have moved towards trying to achieve an award. Their other roles for example in leadership have not yet been assessed.

Daphne Jackson Trust

6.33 This organisation is an independent charity, set up in the late 1980s, that offers two year fellowships to help female scientists, technologists and engineers return to work after a career break. There is no specific evaluation of the impact of the organisation, but details of the numbers of women who have been funded by the organisation can be found.

Professional organisations and societies

6.34 Many professional societies have special initiatives and groups for their female members. These link women within certain sub-sectors of the economy, provide mentoring and networking services, and also often have links to appropriate departments in universities. Examples of organisations with such programmes include National Association of Women in Construction, and the Royal Academy of Engineering.

6.35 There is generally no evaluation of the impact of these schemes. If any data exists it is in the format of numbers of members in relation to the overall number of women working in a particular specialism, or the number of women who have engaged with a particular intervention or network. There is little evaluative consideration of these schemes in the long run. The impact of this participation, whether positive or perhaps negative, has not been evaluated on a large scale. Some examples of the initiatives, and their actions, are listed below.
The Institute of Physics

6.36 The Institute is involved in organising Project Juno, which aims to improve the representation of women in physics. The work undertaken by this project includes work with schools and other educational establishments to affect the pipeline progression of women, as well as a Project Juno Code of Practice which provides practical ideas for actions that departments can take to address the under-representation of women in university physics (IoP, 2008).

Royal Society of Chemistry

6.37 The Royal Society is involved in various different initiatives and in conducting research into women in science, and is actively working to combat the problems faced by women in science, which they believe can only be fully combated by action originating from within science. It is also engaged in compiling statistics on undergraduate and graduate students, with information on attrition rates.
Increasing female participation in SET.

General interventions which operate at a variety of levels and on a variety of areas.

- Educational interventions including curriculum change, encouragement to pursue a career in science, and careers advice.
  - e.g. Women into Science and Engineering (WISE)

- Networking Organisations at various levels
  - e.g. Interconnect, professional societies

- Individual company and private sector initiatives

- Employers

- Schools

- Universities

- Academia

- Employment

- Organisations which seek to provoke changes in cultures within academic science
  - e.g. Athena Project, the Athena Forum, Athena SWAN charter

- Organisations that help women return to science
  - e.g. Daphne Jackson Trust

- Public ideas and wider culture perceptions

- Science policy in general
  - e.g. Science for Scotland

- Equal opportunities policy and equality duties e.g. Equality Duties

- General interventions which operate at a variety of levels and on a variety of areas.
  - e.g. the UKRC
7 ECONOMIC IMPACT

7.1 Concern has been expressed regarding the potential economic impact of the under-utilisation of women’s skills in SET and the overall effect on the wider economy (UKRC, 2010, Biochemical Society, 2010, http://www.biochemistry.org/PublicAffairs/Womeninscience.aspx, accessed 10th August 2010). This section explores these issues, utilising the information set out in previous chapters to develop as comprehensive a picture as possible.

Models and parameters

7.2 Measuring the total economic impact of women in science is a challenging prospect. Recent work has aimed to measure some aspects of the impact of science on the economy. For instance, the OSI and Treasury Steering Group report on measuring the impact of science states that measuring the economic impact of one intervention or policy was impossible, and instead aimed to measure the health of the science and innovation system overall (OSI & Treasury Steering Group, 2007). These problems with measuring the influence of science in the economy have an effect on measuring the impact of women in science.

7.3 There are very few estimates of the economic impact of the loss of women in science. The UKRC states that the loss of women in science costs the economy £2 billion annually (UKRC, http://theukrc.org/resources/why-genderequality, accessed 19th July 2010). This was the only estimate of cost to the UK economy found in any of the literature. No estimates of the impact on the Scottish economy were found.

7.4 The UKRC figure was derived as follows. The average lifetime earnings of a woman with a SET degree were obtained from Dearden et al. (2006). This was then divided by number of years of employment, in this case assumed to be 40, to derive the annual mean salary for this group of the population. The Labour Force Survey 2008 was then used to determine the number of female SET graduates who were not in employment (ILO unemployment or economically inactive). The annual average figure was then multiplied by the number of economically inactive female SET graduates to produce the overall annual impact on the economy. The UKRC acknowledges that this method was unable to capture all the economic impacts of the loss of women in science. This method was used as it allowed an estimate to be created and disseminated quickly (UKRC, email from UKRC staff via website query, 20th July 2010).

7.5 There is also no easily identifiable work that sets out a framework for measuring the impact of loss of women in science, or that states the data or parameters needed to make a full assessment. This means that the following discussion of economic impact was developed from the literature discussing women in science. For these reasons, the various parameters and considerations listed below may prove conflicting or difficult to model.
When modelling the economic impact of the loss of women in science, it should also be borne in mind that positive economic effects could also be ascribed to the “loss” of women in science. SET subjects provide a good basis for a large range of careers, and are often marketed in this way in order to attract more students (Manchester University, 2010). Annual Population Survey employment rates indicate that women with STEM degrees have slightly lower employment rates (80.2%) than men with STEM degrees (85.3%) and also slightly lower employment rates than all those with a degree (men 85.9% and women 85.1%) (ONS, April 2009-March 2010). Annual Population Survey data sample sizes are too small to be able to determine in which industry men and women with STEM degrees work (ONS, April 2009-March 2010). Some of the “loss” of SET qualified adults to other sectors could therefore be seen as a result of the wider usefulness of the skills these degrees provide. This may well also generate value as their skill sets could attract investment and jobs in other sectors.

Measuring the economic impact of the loss of women in science includes measuring several areas of impact and would require a range of data. The complexity of these impacts is illustrated in the economic impact map on p32. Such a model would have to take into account these different effects, as the following section explains:

- Training costs: measuring the costs of training women in science if they are then lost from SET careers. This would encompass measuring costs from schooling upwards to postgraduate level for training women in science, and information on the proportions who persist in SET at various levels. This would then allow the potential costs of training women in SET who do not pursue careers directly related to their training to be identified. Nevertheless, it should also be considered that not all these costs should be considered as loss, due to the transferable skills acquired from a degree in SET.

- Costs to women themselves: measuring the potential costs, in terms of lifetime earnings, for SET qualified women who discontinue their participation in SET at various levels. The proportion of women in SET who wish to pursue a career in this field would need to be known to calculate this. This would require information on the career aspirations of women starting SET careers, and how these change as their careers progress. Typical earning patterns for women in SET, as well as detailed data on the career points and ages at which women left science would also be needed. In this way, the costs to women not pursuing an intended career in SET could be calculated.

- Measuring the potential losses to business from a less diverse workforce, taking into account the various different arguments made about the potential impact of women in SET business put forward by the business case. This would entail collecting data on the performance of businesses with differing compositions of workforce in order to identify the potential losses due to a lack of a diverse workforce as well as collating data on the numbers and proportions of businesses with various different employee
profiles. This would allow the total loss of profit due to a lack of a diverse workforce to be calculated.

- The impact of international migration should also be considered. Scotland is not a closed economic system and can therefore attract skilled workers from other countries. This might not necessarily re-address the gender imbalance regarding women’s representation in science, however, it might possibly offset the skill shortages due to loss of women in science and reduce the overall costs to the economy. Migration, and the associated costs, should therefore be considered when modelling the economic impact.

- Academia and scientific methods: measuring the potential economic impact of loss to academia, and knock on losses to business, due to limited input of women into science, the methodologies of science and the conclusions drawn. This would be difficult to calculate based on existing types of data as there is no comparative example of academia that includes equal proportions of women.

- Impact in the rest of the economy: the impact of SET qualified women leaving SET to work in other sectors of the economy which have demand for SET skills. This could have a positive value in attracting other sorts of investment and generating other types of wealth, and in the individual career trajectories of women themselves. The potential positive impacts of these trends should be balanced against the negative aspects detailed above. This would require data on the proportions of women with SET degrees pursuing non SET career paths, and information on their career trajectories and earnings. From this the difference between non-SET/sector specific lifetime earnings and lifetime earnings in SET could be calculated in the same way as it was calculated for women leaving SET, and the overall impact of this calculated.

- Costs of interventions. Although these could not necessarily be regarded strictly as costs to the economy due to the under-representation of women in science, it might be instructive to consider the costs of past and existing initiatives aimed at increasing the participation of women in science, and balancing these against the costs listed above. This would require data on previous spending on initiatives for women in science, adjusted to current prices. Information on current spending on increasing participation for women in science would also be needed.

7.8 The various parameters listed above set out the chief economic impacts of the loss of women to SET. The diagram on the next page maps these impacts and gives a visual representation of how the factors relate to each other. It also sets out what data would be needed to develop a model to measure the actual costs of the various impacts. The map shows how the factors contribute to direct costs, reduced productivity and other effects on the economy, and how these all feed into the overall effect on the economy.
Overall impact on the economy of loss of women in science

Costs to academia and scientific research due to lack of diverse workforce.
Data: as yet unknown.

Costs of interventions and policies.
Data: information on costs of initiatives past and present.

Impacts on the rest of the economy, both positive and negative.
Data: information on the characteristics, ambitions and career trajectories of women who left SET at various levels and those who stayed.

Direct costs

Wider effects on the economy

Training Costs
Data: costs of training women in science, and persistence rates to various levels of education.

Costs to businesses of having a less diverse workforce
Data: profits of businesses with different employee profiles, and the overall proportions of businesses that fit these different profiles.

Costs to SET qualified women themselves in terms of earnings.
Data: differences in income between groups according to qualification and career path chosen.
8 INTERVIEW ANALYSIS AND RESULTS

8.1 Analysis of the information gathered during the interviews revealed a wide range of themes relating to women in science. The following analysis organises these into six main categories, and synthesises responses gathered from all of the interviews. The interview themes and schedule are provided in Appendices One and Two, p.p 44-47.

Career choice

8.2 One factor that was important to most participants was their experience of science at school. Several specifically stated that it was a key motivating factor, and in all but one of these cases, ambitions to pursue a career in science were set while the participant was at school. This highlights the importance of ongoing encouragement and intervention at this stage in individuals’ academic careers.

8.3 Family experiences and support were also mentioned by some participants. However, one participant talked about active discouragement and lack of support from family. Others did not mention family factors at all. Family support thus emerges as a key, although not universal factor in encouraging participants to pursue a career in science.

Workplace cultures

8.4 All participants were keen to emphasise that workplace cultures in science had positive aspects, that they had had positive experiences on many occasions, and that the negative experiences discussed formed only part of their experiences. Some participants stressed the support offered to them by male colleagues and lecturers, giving examples of occasions on which they had received advice, guidance and support.

8.5 Nevertheless, more negative experiences were also discussed by participants, and even those who described their experience as positive overall simultaneously gave examples of practices that could be regarded as negative.

8.6 Feelings of isolation and exclusion were mentioned directly by two participants, and referred to by others. Participants highlighted that even where colleagues were friendly, being one of few women, or the only woman, in a workplace was odd and isolating. The behaviour of other members of staff often added to these feelings of isolation, with certain behaviours, even if well meant, acting to reinforce difference. Isolation from male forms of networking and socialising was also discussed.

8.7 Outright negative attitudes to women in science were also highlighted by some participants. The range of instances in which these were of influence was much wider than solely in the workplace, with perceptions of science in schools and in society more generally all being mentioned as problems. Negative attitudes from within workplaces were also present. Participants
discussed occasions on which jokes and comments had been directed at them. One participant also reported significant episodes of direct discrimination in terms of pay and other factors. There were, thus, still occasions on which women faced discrimination within the workplace.

8.8 Another issue highlighted by all participants was a lack of discussion of the issues relating to women in science. All participants stated that these issues were not widely discussed in the organisations for which they had worked. Where participants had sought or received information about women in science, this information had come from alternative sources.

Work life balance

8.9 Several participants highlighted the long hour’s culture in academia as a problem in establishing a work life balance. Some claimed there had been a change in this culture over time. The flexibility of being able to work from home or to plan one’s own schedule within academia was mentioned as a counterbalancing factor. Nevertheless, long working hours remained a fact in academia. Long hours at the early career stage were also seen as a way to lay the foundations for flexible working later on in a career.

8.10 There was also some discussion of cultures within other scientific organisations, for example, industry. These were seen by some participants as having a more positive work culture with greater opportunities for flexible work patterns. However, others discussed their experiences in industries with long hour’s cultures. Work-life balance, thus, varied according to industry type and individual workplace.

8.11 The possibility of a need for flexible working for all staff, male as well as female, was highlighted by the participants. Use of flexible working arrangements by a wide range of staff was seen by some as of particular importance in establishing a positive culture within an organisation. Nevertheless, most participants assumed flexible working was a response to the need to balance work and childcare commitments. This association indicated an interesting dimension to how flexible working is thought about.

8.12 All participants stated that there was relatively little systematic support for flexible working within their organisations. Such arrangements were usually available, but were usually arranged on an individual basis. The way in which access to these arrangements depended on personal contacts and negotiation was also highlighted. This could lead to unequal access to such arrangements.

Impact of initiatives

8.13 Awareness of initiatives was reasonable, with the Scottish Resource Centre for Women in Science, Engineering and Technology being mentioned most often. All participants were aware of at least one initiative, and involved in at least one initiative, although the degree of involvement varied considerably between participants. The way in which participants were selected means that
they were likely to have reasonably good awareness of initiatives, and so this pattern of awareness should be approached with caution.

8.14 Participants reported a positive experience with the initiatives in which they had participated, although the exact degree of positive response varied. The most enthusiastic participants viewed initiatives as having significantly contributed to their decision to choose a career in science. Some stated that if initiatives were scaled back then there would be deterioration in the situation for women in science. Others however felt that the initiatives did not wholly address their needs. Nevertheless, all participants saw initiatives as positive and thought they should be continued.

8.15 The role of individual organisers in initiatives also emerges. Many initiatives within organisations such as universities were run by individuals or small groups. This reliance on individuals to organise schemes meant that momentum could be lost if the individuals involved were unable to continue their role for whatever reason. Two participants were unconvinced that existing initiatives had been robust in the face of changes in management and personnel, and that more was needed in order to make initiatives sustainable in the long term.

8.16 The potential of mentoring to help career progression was discussed by participants. Some noted the positive effect mentors had had on their own careers at various points, whilst others stated that the lack of availability of mentors had hindered their career choices. Role models were also mentioned by most participants as an encouraging factor and an example of what could be achieved. Conversely, another participant highlighted that the lack of senior women had been a factor in convincing them to leave an employment sector. Other participants noted the positive effects of networking with other women in science as a source of support and of information.

8.17 Participants variously were unaware of equality duties or sceptical about their impact. Awareness of equality duties was noticeably poor among younger and less senior participants. Among those who were aware of the duties, responses were also not positive. Some participants claimed that the duties had been “a paper exercise” and were poorly understood at lower levels within organisations. Nevertheless, one participant expressed the hope that equality duties would have a positive effect by prompting organisations to think about gender.

Scotland specific

8.18 Participants did not highlight any factors that were specific to Scotland in terms of career choices, universities, workplace culture, work life balance, or equalities.

8.19 Some discussed initiatives and events that only operate within Scotland. The two mentioned most often were Interconnect and the Scottish Resource Centre for Women in SET.
8.20 The high visibility of female scientists in Scotland was also mentioned by most participants, with most of them mentioning Anne Glover, in particular, as a positive factor for women in science in Scotland. This response must be approached with caution in light of the information given to participants about the project. Nevertheless, the fact that this was mentioned in all of the interviews does indicate that positive senior female role models are, at least, of some importance.
9 CONCLUSIONS

9.1 This report has examined the situation for women in science in Scotland and the wider UK context. It has provided an overview of the situation in terms of representation, the reasons that have been suggested to explain this situation, the initiatives and policies that have attempted to tackle the various problems that have been identified, and their results and evaluation. The potential economic impact of under-representation of women in science has also been explored, and the parameters needed for an economic model discussed. The report also includes the results of semi-structured interviews with female scientists that were conducted in order to explore these factors in more depth.

9.2 Evidence from the UK and Scotland more specifically shows that women are still under-represented in science. Patterns of horizontal and vertical segregation persist. Women are significantly under-represented in particular sciences, such as engineering, and are also under-represented in the all sciences at higher levels. The under-representation of women increases at all levels from university upwards. These patterns have shown only limited change over time. Scotland is typical of wider patterns in this respect, and the situation in Scotland is not markedly different from that in other countries.

9.3 The situation has implications for a number of areas. The low representation of women in science has been regarded as a concern as it is a significant point of inequality and should thus be tackled in the interests of equality and fairness. There are also negative cultural effects of this within science. Other arguments have concentrated on economic factors and highlighted the negative implications of under-representation of women in SET employment for the economy and business. The implications of these justifications for action have been contested by some authors, who claim that the recent primary focus on economic aims can perpetuate problems for women in science by singling them out as different from normal scientists, and thus perpetuating cultures which see women as different and thus potentially unsuited to scientific careers.

9.4 There is a significant body of literature examining the causes of the under-representation of women in science, and a small number of works concerning the specific situation in Scotland. The literature indicates a wide range of reasons for the patterns observed and the most prominent of these factors are discussed in the literature review. Factors within education at various levels have been suggested as a significant causal factor. Influences from teaching and learning environments can be significant in determining patterns of persistence, as can attitudes from male peers and lecturers. Negative and unwelcoming workplace cultures are also discussed by many authors as a factor in deterring women from pursuing careers in SET. Access to flexible working can be a particular problem within science, as can the close association between characteristics such as logic and technical knowledge and stereotypical ideas of masculinity. There can also be issues within specific career paths, such as academia. The literature thus indicates that the
attrition rate has multiple causes at a range of levels, and these can vary between sciences.

9.5 The issue of women in science links to a number of other policy areas, namely science policy, equalities policy and education policy. Various different initiatives within these areas have implications for the recruitment and retention of women in science, indicating that a cross policy response is needed.

9.6 There are also a wide range of initiatives and policies aimed at increasing the participation of women in science. These initiatives are varied in terms of their approach, and operate on many different aspects and levels, such as in education, university, academia and the workplace. Common types of action include providing information and advice to women, institutions and businesses, facilitating use of role models, mentors and networking and providing best practice guides in order to change institutional practices and structures. In this way, initiatives act on a complex number of interacting levels to try to reduce under-representation.

9.7 There is little detailed or in depth analysis of the impact of policies aimed at increasing participation and retention of women in science. There has been some limited evaluation of the impact of parts of programmes, but generally the overall impact of these programmes remains unexplored. For this reason, making specific recommendations of policies that have worked based on previous experience is difficult. Further evaluation would be needed before such recommendations could be made.

9.8 There is very little literature modelling the economic impact of the loss of women in science. A detailed exploration of the parameters identified from the more general literature on women in science is provided to indicate the possible ways a model could be created. These are complex and touch on many different areas of the economy, and it is acknowledged that they may prove either incomplete or incompatible with modelling. An economic impact map has been produced to show more clearly the various different things that would need to be considered in order to build up a full picture of the effects on the economy.

9.9 A series of interviews was conducted in order to explore various themes in more depth. The results indicated several key points. Participants frequently mentioned schooling as an important factor in their decisions to pursue careers in science, indicating the importance of intervention at this level. Discussions of workplace cultures showed mixed results, with participants highlighting the positive aspects of their experience, but also bringing to light significant negative experiences as well. Participants also indicated problems in the workplace, such as a lack of structures to ensure access to flexible working. Their experiences with initiatives were generally positive, although this varied, but concern was expressed that initiatives needed to be robust in order to withstand change. The interviews thus highlighted several areas in need of attention and ways in which initiatives could be improved.
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UKRC, email from UKRC staff via website query, 20th July 2010.

APPENDIX ONE: INTERVIEW THEMES


Participants will be asked questions about the following themes:

1. Background and position as scientists, and career outline.

2. Career progression, career motivations and the decision to pursue a career in science.

3. Career challenges and how easy it has been for them to pursue a career in science.

4. Experiences of workplace and organisational cultures in science.

5. Establishing a work-life balance, and experiences of organisational structures to support achieving a work/life balance.

6. Experiences of initiatives and policies which aim to improve participation and retention of women in science.

7. Experiences of best practice in recruiting and retaining women in the scientific workplace.

8. The impact of equalities legislation on scientific communities.

9. Scientific careers in Scotland and any factors specific to Scotland in terms of access to or participation in scientific careers for women.

10. Any other factors the participant thinks are relevant and that have not already been covered.
APPENDIX TWO: INTERVIEW SCHEDULE

Scottish Government Women in Science and Engineering Research Project
Interview questions

**Introduction**
Confirm consent to record the interview.

1) **Career trajectory**
To start off with, I would like to ask you a few questions about your career in science.

Could you give an outline of your career so far?

What is your current position?

2) **Motivations and career choice**
I would like to ask a couple of questions about what motivated you to choose a career in science.

Why did you choose to pursue a career in science?

Prompts:

Can you tell me a bit more about how and when you decided to pursue a career in science?

3) **Challenges**
We have talked a little about career choice and motivations. I would now like to ask you how easy it was to pursue a career in science.

Have you faced challenges or difficulties in pursuing your career in science?

Prompt:

Could you elaborate on how these emerged and how you overcame them?

4) **Workplace culture**
I would like to ask you about your experiences with the culture/cultures of the organisations you have worked for.

What have been your experiences of workplace cultures in jobs/positions in science?

Prompts:

Have workplace cultures in science affected your career?
Have you noticed differences in workplace cultures within science?

Information: for instance, between different university departments or workplaces, or between undergraduate and graduate study.
5) Working life and working patterns
We have talked about cultures in the workplace. I would now like to move on to talk about establishing a work-life balance.

What has been your experience of establishing a work life balance?

Have you faced any problems in doing this?

What practical supports are in place in your organisation to help people achieve work-life balance?

6) Initiatives and policy
I would like to ask a couple of questions about initiatives and policies aimed at increasing women’s access to science, and women’s participation and retention in science.

Have you participated in any initiatives or policies for women in science, either as a service user or organiser?

If yes:

What are your experiences of these initiatives?

If no:

Could you tell me a bit more about why this is the case?

7) Best practice
We have talked a bit about initiatives and policies aimed at women in science. I would now like to ask you some questions about best practice in recruiting and retaining women in science.

Could you give examples of where you have seen best practice in action?

Information: for instance best practice could include a commitment to making sure flexible working practices are easily available to all, that work culture is equitable, for academic departments signing up for the Athena/SWAN charter.

If not answered or short answer given, prompt:

Do you think it is important for organisations in science to engage with best practice?

8) Equalities approaches more generally
I would like to ask you about the impact of equality duties on science.

In your experience, had the introduction of equality duties had any effects on your organisation?
Information: equality duties impose a positive duty on public bodies, so that they have to actively promote equality rather than preventing inequality.

9) Scotland specific factors
I would like to ask if you have experienced anything specific to Scotland in terms of female access to or participation in scientific careers?

If yes, could you tell me a bit more about this?

10) Additional points
I would like to ask you if there were any things not yet covered that you would like to discuss?

Thank them for their time and input
APPENDIX THREE: UKRC STEM SUBJECT CLASSIFICATION (UKRC, 2009)

Subjects allied to medicine
Anatomy, Physiology and Pathology
Pharmacology, Toxicology & Pharmacy
Medical Technology

The following subjects were excluded from Subjects allied to Medicine: Broadly-based programmes within subjects allied to medicine; Complementary medicine; Nutrition; Ophthalmics; Aural & oral sciences; Nursing; Others in subjects allied to medicine

Biological sciences
Broadly-based programmes within biological sciences
Biology
Zoology
Genetics
Microbiology
Sports science
Molecular biology, biophysics & biochemistry
Others in biological sciences

The following subjects were excluded from Biological sciences: Botany; Psychology.

Physical sciences
Minerals technology
Broadly-based programmes within physical sciences
Chemistry
Materials science
Physics
Forensic & archaeological science
Astronomy
Geology
Ocean sciences
Physical & terrestrial geographical & environmental sciences
Others in physical sciences

Mathematical sciences
Broadly-based programmes within mathematical sciences
Mathematics
Operational research
Statistics
Others in mathematical sciences
Others in mathematical & computing sciences

Computer science
Computer science
Information systems
Software engineering
Artificial intelligence
Others in computing sciences

**Engineering & technology**
Broadly-based programmes within engineering & technology
General engineering
Civil engineering
Mechanical engineering
Aerospace engineering
Naval architecture
Electronic & electrical engineering
Production & manufacturing engineering
Chemical, process & energy engineering
Others in engineering
Minerals technology
Metallurgy
Ceramics & glasses
Polymers & textiles
Materials technology not otherwise specified
Maritime technology
Industrial biotechnology
Others in technology

**Architecture, Building and Planning**
Architecture
Building
Landscape Design
Planning (Urban, Rural and Regional)
Others in Architecture, Building and Planning