Meta-analysis of gender and science research – Country group report

UK and Ireland countries

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This is one of the thematic reports of the study *Meta-analysis of gender and science research*, a project of the 7th RTD Framework Programme of the European Union (RTD-PP-L4-2007-1), commissioned by DG Research to the consortium led by CIREM (Spain) and made up of Université Libre de Bruxelles (Belgium), Inova Consultancy Ltd. (United Kingdom), Fondazione Giacomo Brodolini (Italy), Bergische Universität Wuppertal (Germany) and Politikatörténeti Intézet KHT (Hungary). The study was carried out between 2008 and 2010.

The purpose of the study was to collect and analyse research on horizontal and vertical gender segregation in research careers, as well as the underlying causes and effects of these two processes.

The objectives of the study were to:

- Provide an exhaustive overview and analysis of research on gender and science carried out at the European, national, and regional levels.
- Make the study results accessible to researchers and policy-makers via an informed bibliography (online database) and a set of reports.
- Steer policy-making on gender and science and define future research priorities within the Framework Programme, in particular through good practice examples and gap analysis in the various research topics.

For the purposes of the study, 'science' was understood in its broadest meaning, including social sciences and humanities as well as research and technological development.

The study covered the research on gender and science produced between 1980 and 2008, in all European languages, in 33 countries: the 27 EU Member States as well as 6 Associated Countries to the Seventh Framework Programme for Research and Technological Development (FP7) (Croatia, Iceland, Israel, Norway, Switzerland, and Turkey).

The study produced five country-group reports, seven topic reports and the final synthesis report:

Country-group reports	**Authors**
Continental countries	Hafsatou Diallo, Danièle Meulders, Síle O'Dorchai & Robert Plasman
Eastern countries	Mária Palasik, Nikolina Sretenova, Robert Takács & Núria Vallès
Nordic countries	Seppo Roivas
Southern countries	Elisabetta Addis & Costanza Pagnini
United Kingdom and Ireland	Cinnamon Bennett, Marina Larios, Louise Norman & Emma Parry
Topic reports	**Authors**
Horizontal and vertical segregation	Danièle Meulders, Robert Plasman, Audrey Rigo & Síle O'Dorchai
Gender wage gap and funding	Danièle Meulders, Síle O'Dorchai, Robert Plasman & Audrey Rigo
Stereotypes and identity	Felizitas Sagebiel & Susana Vázquez-Cupeiro
Science as a labour activity	Maria Caprile & Núria Vallès
Scientific excellence	Elisabetta Addis with the assistance of Costanza Pagnini
Gendered innovations	Londa Schiebinger, Ineke Klinge, Addison Arlow & Sarah Newman
Policies towards gender equity in science and research	Cecilia Castaño, Jörg Müller, Ana Gonzalez & Rachel Palmen
Synthesis report - Authors	
Maria Caprile (coord.), Elisabetta Addis, Cecilia Castaño, Ineke Klinge, Marina Larios, Danièle Meulders, Jörg Müller, Síle O'Dorchai, Mária Palasik, Robert Plasman, Seppo Roivas, Felizitas Sagebiel, Londa Schiebinger, Núria Vallès, Susana Vázquez-Cupeiro	

All the reports and the online database (Gender and Science Database, GSD) are available at the website of the study: **www.genderandscience.org**

Executive Summary

Introduction

This report presents a review of the Anglo-Saxon literature catalogued in the *Gender and Science Database GSD.* These publications explore the situation in the United Kingdom (UK) and Ireland, spanning the last three decades. In the UK and Ireland scientific endeavour is captured by the abbreviations SET; Science Engineering and Technology or STEM; Science, Technology, Engineering and Mathematics. Whilst these abbreviations include subjects as diverse as Medicine and Building and Planning they do not include Economics or Psychology which are defined as Social Sciences.

The literature about gender and science is not equivalent in the UK and Ireland. The majority of publications are concerned with the UK experience. This can be explained by the historical development of Ireland's economy and scientific labour force, which lagged behind that of the UK and then in the last decade has been dominated by inward investment and migration of skilled workers into high technology sectors. Although Irish research is under-developed, robust political and legislative commitments to gender mainstreaming in Ireland provide a helpful context for future academic investigation.

The areas of interest pursued by UK researchers have been shaped by a number of drivers including: politicians' concerns for the country to remain globally competitive through scientific innovation delivered by a skilled workforce; lobbyists' campaigns for equal rights for women employees; and female academics' challenges to the cultures and practices of their own science disciplines. The feminist perspective informing much of this work has supported a primary focus on *women's* experiences under the heading of 'gender'.

Features of the Anglo-Saxon research literature

Political debates about gender and science
The literature has been grouped into three phases or positions, which loosely map onto each decade. This typology has drawn heavily on the analysis provided by Cronin and Roger's examination of initiatives in the UK Higher Education sector (Cronin and Roger 1999) and Glover's consideration of consecutive policy phases across all science sectors (Glover 2001). The emerging critique of each position has informed the development of the subsequent position, producing overlaps between them. The positions are:

- ***Recognition of SETs' economic contribution and the need to attract more scientists (1980s)*** Theories of gender socialisation and assumptions about the popular image of science as unattractive, prompted the actions to encourage a greater number of female entrants into science qualifications and careers. This literature problematises the nature of women's aspirations rather than the nature of scientific ontology, pedagogy or occupations.
- ***Recognition of the 'female condition' and the need to level the playing field (1990s)*** This position draws on wider debates about discriminatory practices, equality of access to opportunities applying them to academic organisations and scientific workplaces. There is a focus on organisational change.
- ***Recognition of scientific gender bias and the need to re-examine norms and values (2000s)*** Critiques of the previous positions provide a body of evidence to challenge the objectivity of science itself; arguing that SET incorporates male values, practices and theories because of its history, practitioners and locations. Rather than women being deficient and choosing not to take up the opportunities on offer to fulfil their potential, they are under-represented because of an unrecognised inherent bias in the social construction of SET environments.

The report highlights the lead provided by the European Union in valuing the contribution of all three positions as the means to reach the goal of gender equality in science.

Data and methodological approaches

The literature draws on different sources of data and methodological approaches according to the three positions raised by the political debate. For example, in the 1980s, a focus on the need to attract more individuals into science directed research towards science education, and statistical data analysis of pupil/student subject choices, academic achievement and progression by sex. A decade later as attention shifted to organisational practices, women's experiences of employment began to be examined using qualitative methodologies and documentary analysis has been applied to organisational policies. Case studies, qualitative interviewing and textual analysis became more prominent from 2000 as more questions were asked about women's motivations, and the 'norms' and values of scientific knowledge creation came to be scrutinised.

Topics covered in the GSD

The GSD has catalogued publications under a series of conceptual topic headings. These are: horizontal segregation, vertical segregation, pay and funding, science as a labour activity, scientific excellence, gender in research contents and policies towards gender equality.

- Most prominent topics: horizontal segregation 51.2%; stereotypes and identity 57.4% (examining women's entry and attitudes towards science) and vertical segregation 45.1% (encapsulating women's retention and career advancement).
- Publications covering science as a labour activity are almost exclusively focused on women's management of work/family commitments than on organisational cultures, which is a relatively new area of research.
- 65.4% of publications address the topics in relation to all the science sectors. Of the 34.6% which focus on specific sectors, the majority (83.1%) are concerned with developments Higher Education. Private/non-profit and business / enterprise sectors feature in only 2.5% and 18.3% respectively of single sector publications.
- There is inconsistent research by scientific field reflecting the sporadic interest of women scientists to challenge their disciplinary norms.
- UK methodological approaches are broadly inline with those of all GSD countries, with the exception of qualitative research techniques which have been used more extensively to capture, compare and contrast scientists' perceptions and experiences.

Findings and gaps

Horizontal segregation

Girls' and boys' engagement with science education begins to decline as they enter secondary school coinciding with a general lack of interest in school rather than a rejection of science. Numbers of exam entrants are maintained pre-16 as the selection of science qualifications is mandatory in many schools, but then suffers a drop at 'A' Level entry. Girls' 'A' Level entry is smaller than that of boys, and although they achieved higher grades in these qualifications, these statistics indicate the beginning of the narrowing of the science career 'pipeline' for women. There are notable research gaps:

- Whilst there has been prolonged and targeted funding in the UK to tackle the gendered selection of science qualifications and careers there is very little evaluation of what has worked and why for either sex.
- There is a lack of research into the detail of horizontal segregation. For example, comparisons of women's employment in academia versus industry, or the public sector (their choice of sector, entry level grade, experiences, attrition rates) and the non traditional entry routes taken by women and men from manual trades to SET professional occupations.

Vertical segregation, pay and funding

In the UK and Ireland senior positions are dominated by men, even in occupations where women are as numerous as men. Attention has been focused on women's professional careers, and the extent to which they have been able to advance to senior levels and secure funding, focusing on the personal and structural barriers they have experienced, particularly those relating to their caring commitments. The gendered nature of organisations is well developed in sociological literature but less so in the literature of the GSD concerned with science organisations, for example more research is needed on:

- The situation of women working below their proven potential, linked to part-time work.
- The feminisation of occupations which are family friendly.

- The operation of male networks and their associated cultures.

It is likely that many men struggle to progress in dominant masculine environments (Connell 1987) but this research has not yet been undertaken in any science discipline.

Stereotypes and identity

The investigation of sex-role stereotypes and identity has been used to explain horizontal segregation in education: pupils' choice of subjects to study at school and university and their experiences in the science classroom. Explanations of vertical segregation have included an examination of gendered stereotypes in the workplace and women's experience and ways of coping with them through the adoption of particular identities.

- Theoretical and empirical research is needed to elucidate further the ways in which gendered binary dualisms expressed through stereotypes, operate in different science disciplines, following the insights provided by the work of Faulkner (2000) and others in the field of Engineering.
- As part of this focus, pupils', students' and employees' acceptance of stereotypes and adoption of gender appropriate identities should be studied for different age cohorts and from the perspective of ethnicity and socio-economic group.
- Whilst there is a growing literature about gendered pedagogy, a systematic evaluation of gender-aware teaching, and in particular, subject content and single-sex classrooms is needed to identify why and how this can further benefit girls and boys.
- Career choices which spin off from experiences of learning are also relatively under-researched, particularly the lag between popular notions of scientists and scientific workplaces and their contemporary reality.

Science as a labour activity

Literature relating to scientific occupations, workplaces and the practice therein has mainly concentrated on issues of vertical segregation. The most prominent conceptual model to explain women's place in science employment is that of the 'career pipeline' which is said to narrow with seniority as a variety of pressures force women out. There are very few studies which examine men's experience of scientific employment, in most cases their experience is assumed to be a homogeneous 'norm'. Other features of the literature include:

- Almost exclusive focus on professional non-manual occupations.
- A focus on women's experience and pursuit of 'work life balance'. Many of these studies are interested in women's preferences and choices but fail to analyse in detail the systems and structures which act to constrain them *in science organisations*.
- Since 1990s research interests have widened to consider the global science labour market including the impacts of the migration of skilled labour, and rapid technological change. Research on Higher Education jobs has looked at managerialism and entrepreneurialism, and includes the commercialisation of scientific discoveries.

Scientific excellence

Demonstrating the achievement of scientific excellence is arguably the biggest hurdle to the most senior and prestigious positions in the scientific hierarchy. It is also a significant determinant of pay. Its definition and the process of assessment are therefore contentious and have been scrutinised for gender bias, as debates about the neutrality of science and women's vertical segregation have been highlighted. The debate in the UK and Ireland has focused on the relative achievements of female and male academics, by discipline, in terms of: their participation in the evaluation processes (criteria setting, scoring, refereeing, journal editing); frequency and volume of research funding applications and success; and their published output. Further empirical research is needed to guide policy intervention. This could include:

- Managerial practices in Higher Education which normalise the pressure on academics to 'publish or perish', undervaluing alternative contributions to the running of successful departments.
- Women's awareness of a gendered bias and hence their decisions about how best to deploy their effort for maximum return.
- Longitudinal research to establish the points of greatest harm and the culminative effect of systemic gender bias over an individual's life time.

Gender in research context

This topic is pivotal both for debates about excellence in science and the development of policy. Its starting point is the acknowledgement that science is a social activity which takes place within a social structure (Buckingham-Hatfield 2000). Hence our understanding of what can be said to exist and the ways we make sense of similar phenomena is socially constructed and therefore transmutable over time, rather than fixed and essential. Undertaking research from this perspective demands a reflexive view of what it is possible to know. Feminists have argued that unequal gender power relations have resulted in scientific agendas which privilege male interests. The following actions are recommended:

- Further documentary analysis of women's past achievements in science to produce a more accurate and enriched account of historical scientific development.
- Extending research addressing 'diversity' in science education and occupations.
- More empirical research into the ways in which organisations and individuals use the claim of 'objectivity' (knowingly, unwittingly) to reinforce stereotypes and practices.
- Compilation of good practice examples of reflexive scientific research and clarification of which methods and ethical undertakings can be most appropriately applied from social science to science settings.

Policies towards gender equality in science

There is a thorough analysis of the ideological underpinning of UK gender equality policies across the three decades; far fewer publications focus solely on policies for gender equality *in science*. Of these, the majority tackle issues within single science disciplines, in particular women's recruitment (position 1 focus). A subset of publications are concerned with the policy instruments, describing localised single programmes and the impact which participants report they have had on their careers. A few publications take a comparative or retrospective view reflecting on a number of different instruments / projects in order to identify criteria for success and the scope for replication and up-scaling. There has been very little evaluation research focusing on the policies and programmes put in place in the UK and Ireland to achieve greater gender equality in scientific research. There is no account of the impact that different decades of policies have achieved in quantitative terms, although there are many personal case studies of participating women's experiences and career trajectories.

Conclusions

- A systematic approach to the collection of statistical data at a national level is required, including mandatory data collection for all funded interventions, the standardisation and consistent use of indicators and more effective synthesis of existing data sets.
- Whilst there has been prolonged and targeted funding in the UK to tackle gender segregation in science there is very little evaluation of what has worked and why. This is a significant weakness as lessons are failing to be learnt and opportunities to share good practice are being lost.
- The majority of work on segregation in science has been carried out by academics, studying public institutions. Very little research has examined the experiences of women and men working in private sector organisations.
- The experience and career development of women and men working in manual trades and as self employed individuals is largely absent from the literature, as are the trajectories of those who enter the science professions via these routes.
- A reseach focus on men in SET is absent from the literature, except in a minority of publications discussing boys' under achievement in schools. The choices which men make and the ways in which masculine cultures are changing or can be changed should be an area for ongoing research.
- Research which has addressed 'diversity' in science (education and occupations) should be extended to consider the educational outcomes, recruitment and advancement of different groups of women and men.

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1. Introduction

This report aims to review the literature of the last three decades on the topic of gender and science as it relates to the situation in the UK and Ireland. Interest in the gendered nature of science; as an occupation, a subject of academic study, and a means of understanding of the world, is well established in the UK commencing in the 1980s. In Ireland, research began in the last decade and consequently the breadth and depth of analysis is far less developed. In the UK contributions have been made by teachers, scholars and researchers in Science, Engineering and Technology (SET), as well as scholars of sociology and social policy with an interest in labour markets, organisations and education. There have also been notable inputs from policy makers attempting to diagnose the issue in order to inform the design of appropriate policy responses or practical interventions. All the publications referenced here are catalogued in the *Gender and Science Database GSD.* In addition, the report's discussion of gender and science has been contextualised in other relevant bodies of work. For example, the concept of 'gender' has been developed within feminist and sociological literatures, and the debate about scientific pedagogy has taken place within the broader study of education.

It is worth noting that the European Union's concern with equality adopted a focus on gender in the mid 1990s when it called for the need to mainstream a perspective which looked systematically at the impact of policies and practices on both women and men. This approach superseded the single focus on women's disadvantage in the policy arena. However, the importance of women's politics in driving the equalities agenda forward has not changed, and the literature reflects this - most commonly looking from a women's perspective. 'Science' as a term also needs unpacking. In the UK and Ireland scientific pursuit is captured by the abbreviations SET; Science Engineering and Technology or STEM; Science, Technology, Engineering and Mathematics. Whilst these abbreviations include subjects as diverse as Medicine and Building and Planning they do not include Economics or Psychology which are defined as Social Sciences. The full list of subjects which these abbreviations refer to are listed in Appendix 1. Lack of time and available literature, has meant that it has not been possible to investigate the topic of gender and science discipline by discipline, despite the fact that the literature suggests that there are significant differences in the gender balance of the labour pools, hierarchies and approach to reform in each scientific specialism.

The report is divided into six sections. It starts by contextualising the working patterns and contribution of women scientists in the historical development of women's engagement in paid work and the structure of labour market opportunities. There is a significant contrast between the UK and Irish labour market developments leaving very different precedents and affecting contemporary opportunities for women. Section 2 takes an overview of the political debates about women's position in science and its gendered nature. Three 'positions' have been identified roughly corresponding with the passing decades and each informing a different set of policy responses. Each position is still apparent in policy making today. The approaches taken towards research can also be seen to correspond to these shifts in perspective (Section 4). Section 3 looks at the factors which shape segregation, both horizontally across occupations in the labour market and vertically within the science hierarchy. These factors are then picked up individually in Section 5 and the GSD literature is reviewed under the following topic headings: horizontal segregation, vertical segregation, pay and funding, stereotypes and identity, science as a labour activity, scientific excellence, gender in research contents, and policies towards gender equality in science. Each topic concludes by identifying the gaps in our research knowledge. A discussion of the research agenda required to address them makes up the final section (Section 6).

1.1 Women's position in the labour market

Archaeology of gender segregation in the UK

Gendered horizontal and vertical segregation is embedded in the historical developments of national economies and labour markets. The effects of segregation may be felt long after the industrial landscape which established them, has declined and changed.

In the UK, the beginnings of our modern labour market began in the post-war period when occupational structures diversified and new technological, social, and educational developments opened up a greater variety of paid employment opportunities for women. Women had demonstrated their ability to work in skilled, physically demanding occupations during the Second World War. They remained an important part of the labour market post-war, however a social and political desire for female domesticity and family growth brought about a partial reversal to pre-war values including a bar on employment following marriage. From 1945 onwards a declining age of first marriage and the expectation that married women would be housewives meant that for the next twenty years women had very short experiences of full-time work (averaging 5-10 years) up to marriage, until their children were no longer dependant and they returned to part-time work, often in a different occupation from that which they had originally worked. The idea of this *bimodal pattern* came to dominate policy making until the 1975s (and arguably beyond) although in women's everyday lives the reality became increasingly more intermittent and flexible as educational opportunities for working class children improved providing them with greater choice in employment. The creation of the NHS further increased demand for women's labour offering a greater range of job opportunities, as well as the decline of certain 'heavy' manufacturing sectors and their replacements by light assembly work, such as electronics, ideally suited to a shift based, low skilled workforce.

Historical working patterns and notions of 'women's and men's work' were deeply ingrained in the practices of employers and popular perceptions at this time. The use of part-time work deployed successfully in wartime to maximise the use of plant and machinery carried over into peacetime in accordance with women's retreat from the labour market during child-rearing years. Even after this trend was dying away and women took up full-time work again in greater numbers employers continued to construct jobs as part-time positions deliberately to appeal to women who wanted flexibility and were satisfied with less pay. The notion of 'women's work' also persisted, and referred to a narrow range of occupations requiring caring and social skills; nursing, primary teaching, cleaning, shop selling, clerical work. Catherine Hakim's study (1981) of trends between 1901 and 1971 established that while horizontal segregation had shifted and broadened the occupations open to women, vertical segregation had grown. Men, through unionised action, occupied a disproportional share of higher skilled, higher status, better paid jobs (Cockburn 1983).

The further demise of manufacturing in the 1980s and growth of service sector employment such as banking services and retail further increased women's entry to the labour market. Women's presence in professional occupations also grew following a decade of participation in higher education, with the associated development of dual earner households. For the first time there developed a material divide *between women*; women who advance to higher level positions with better pay, prospects, training opportunities, maternity and tax benefits, and women in low skilled, low paid jobs who struggle to maintain themselves and their families through their own incomes.

Horizontal and vertical segregation in Science Engineering and Technology SET sectors[1] reflects these main trends in women's labour market engagement in the UK. Important precedents were set for women's involvement in skilled trades and manufacturing processes during the Second World War which were given up in the peace which followed; an advantage

[1] SET Science Engineering and Technology or STEM Science Technology Engineering and Mathematics are the commonly used abbreviations for the sciences in the UK and Ireland. The full range of subjects which these abbreviations refer to are listed in Appendix 1, they include subjects allied to medicine, and architecture, building and planning.

which has not been regained. In the science professions, research has shown segregation within the SET sectors themselves, with certain occupations and science specialisms attracting high numbers of female entrants and so becoming 'feminised' (and subsequently less valued). Women's dominance of General Practice medicine has been given as one such example. Vertical segregation illustrated by the 'pipeline model' (Berryman 1983) has been described as more intensive and pervasive in SET than in other sectors owing to the continued dominance of men in the sector.

Gender segregation in the nascent labour market in Ireland

In Ireland the pattern of women's engagement with the national labour market has been very different. At the turn of the century very small numbers of women were engaged in paid employment. Domestic service provided the highest source of employment with a slow expansion of opportunities in full-time positions, prior to marriage, in shops, offices and industry. The civil service, a major employer for middle class women in an economy that was generally un-dynamic and stagnant, operated a bar on married women into the 1950s and was not outlawed until 1971 (Cullen Owens 2004) a trend reinforced by Ireland's very 'traditional' family culture.

Ireland's transition to independence in 1922, followed by poor political leadership (especially on matters of economic policy) but rising popular aspirations, led to a massive exodus from the country between the 1940s and 1960s, composed of roughly similar numbers of women and men (Daly 2006). This exodus only began to slow in 1950s when much needed manufacturing and industrial employment was created. A more dramatic economic transformation began in the late 1980s following a change of government and significant aid from the European Union which was used to improve Ireland's education system and physical infrastructure. A combination of these factors along with low corporation rates, a low waged economy, and government subsidies succeeded in making Ireland an attractive location for global high-tech businesses, including Dell, Intel and Microsoft. The time zone difference between America and Ireland has also been seen as advantageous in facilitating this significant inward investment.

Consequently total employment in Ireland grew by 50% in the period 1993-2002, whilst unemployment fell from 16% to just over 4%. One of the most striking features of this growth was in women's labour force participation. Total women's employment increased by 60% almost twice the growth rate among men (32%) (McGuinness, McGinnity, O'Connell 2008). Women's total share of employment rose from 37% in 1993 to 42% in 2004 (Russell, O'Connell, McGinnity 2007). This continued a trend which had started in the 1980s when women's total share in employment stood at only 29% (1981). During this earlier period, part-time jobs accounted for the growth in employment. By 1997 this had slowed to the same rate of growth as that of full-time jobs.

In 1997, 32% of women were working in part-time jobs. Whilst the majority of these jobs were skewed towards routine, lower skilled occupations (20% in personal services, sales, clerical jobs and 15% in unskilled occupations) 23% were in managerial, professional and associate professional occupations. Looking at women's employment by sector, employment gains have been highest in Transport and Communication and Finance and Business, sectors characterized by medium to high skills. 43% of women's full-time jobs are in managerial, professional and associate professional occupations. Part of the increase in employment coincided with increased inward migration, encouraged by government policy. However, not all of the new jobs were occupied by resident or native women. Barrett and Trace (1998) have shown that the educational attainment of immigrants during the 1900s increased the supply of skilled labour by 3.2%.

The labour market structures of Ireland's modern labour market do not have a long history, and are built around service and high technology sectors. However, they will not have been untouched by assumptions about women's work and part-time employment prevalent in the culture of their inward investors arriving from across the Atlantic. Joan Acker (1992) has shown the ways in which norms are shared and reinforced though relationships and exchanges between organisations. Research looking at gendered vertical segregation in Ireland is confined to the Higher Education sector and particular disciplines such as medicine where women are

already a majority of graduates and expectations for progression are high. Horizontal segregation on the other hand is a matter of national policy. Echoing UK concerns expressed about the need for skilled labour to ensure economic prosperity the Irish government has issued clear commitments to increasing women's participation in SET sectors (Allan 2001).

Science - a key element of the Anglo Saxon economies

Successive UK and Irish governments have identified that success in a global market place will rely on advanced scientific and technological knowledge leading to increased exports and efficiencies in national production. Creating the right conditions to innovate and expand is crucial element in achieving this project which centrally relies on a ready supply of skilled labour. Looking at labour force projections, governments have concluded that the talents of a broader section of the population need to be captured as well as new recruits secured. Targets have been set in education and employment policy to tap into women's labour. In the last decade social policy has been used to provide more a conducive tax structure and childcare infrastructure to encourage women to participate. In the late 2000s, the prospect of slow or contracting economic growth, has served to strengthen these intentions; the contribution of science and technological innovation and entrepreneurism has become more, not less significant. The governments of UK and Ireland have taken swift steps to identify innovation in SET sectors as a key element to the path to recovery and to reassure the science community of their continued financial investment and policy support. The next section examines the political debates about the importance of science and the scientific workforce. It discusses the ways in which the debate has matured from 1980 to 2007.

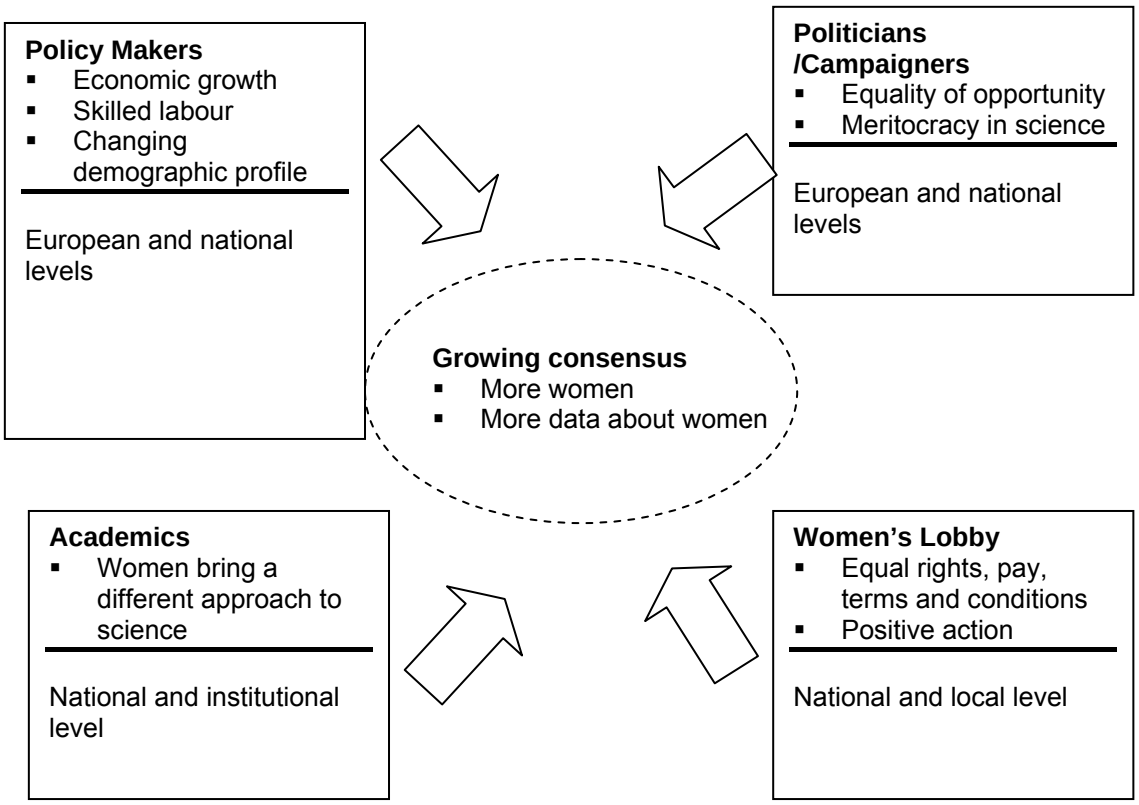
2. Main political debate on gender and science from 1980-2007

This section takes an overview of the debates on women, gender and science, identifying distinct positions emerging in each decade. The ways in which each position and its critique has informed the subsequent debate is discussed. The section concludes by examining the European perspective to show that whilst each position has its detractors and weaknesses all three put forward useful and valid ways of tackling gender inequality in contemporary science labour markets.

2.1 Women's professional scientific careers

The issue of women's under-representation in professional scientific employment has gained greater attention and importance in the last three decades. There have been an increasing number of dedicated conferences. In addition, a variety of European and national bodies have articulated concerns by commissioning reports and nominating funding assistive funding streams. Prominent stakeholders have included policy-makers, civil/servants, politicians and women scientists. Their contributions reflect a growing consensus that the presence of more women in science, and more evidence about their trajectories, is needed to achieve the European goal for an inclusive and successful common market. Policy makers have focused on the necessity of securing economic growth and competition through meeting the rising demand for highly skilled labour, whilst politicians and women's lobbyists have argued for equality of opportunity and meritocratic occupational structures to harness and express the potential contribution of all individuals in society.

Figure 1: Political drivers for increasing women's participation in professional scientific employment



A number of prominent UK based studies have been undertaken to describe and conceptualise the policy changes and initiatives which have taken place to address women's representation in SET employment. Notably, Cronin and Roger's examination of initiatives in the UK higher Education Sector (Cronin and Roger 1999) and Judith Glover's consideration of consecutive policy phases across all science sectors (Glover 2001). The following discussion draws heavily on their typologies and conclusions and attempts to bring the history of political debate up to date. Cronin and Roger examined a range of UK and international initiatives, condensing the underlying assumptions and corresponding actions into five positions which loosely chronicle the main approaches to women's under-representation in SET during the 1980s and 1990s. Glover has followed a similar approach, finding that the focus of attention has shifted from entry and qualification issues to retention and attrition rates, using as her data the policies of successive UK governments. Both studies include critiques of the positions they have identified.

2.2 UK trends in political debates on gender and science

Recognition of SETs' economic contribution and the need to attract more scientists (Position1)

The initiatives for women in science which developed in the early 1980s had their roots in a series of government reports starting in the 1960s which began the debate about the centrality of science for national economic growth and increasingly for national global competitiveness. These were underpinned by Human Capital Theory (that individuals build up personal 'capital' – skills and experience - which they then sell in the labour market place, Becker 1964) and made the unquestioned link between levels of qualification and a highly skilled workforce as vital investments for growth. The reports were initially focused on an observable 'brain drain'; a net outflow of UK-trained scientists and technologists to better paid jobs mostly in North America. At the same time fewer men were undertaking science qualifications. In the context of a diminishing supply of science '*man*power' women were identified as an 'untapped pool of labour' in the Dainton Report (1968). The report made no differentiation between the relative and potential contributions of qualified women and men to scientific invention and discovery; the unquestioned conception of science was that it was a neutral and objective endeavour and scientists were genderless beings.

Theories of gender socialisation and assumptions about the popular image of science have informed the actions proposed to attract a greater number of female entrants into science qualifications and careers. They are presented as 'barriers' to overcome and include:

- gendered childhood toys and parental reinforcement of 'traditional' gender roles which deter girls from developing an interest in science
- public perceptions of science as 'dirty' and involving heavy machinery
- public perception of SET subjects as not 'creative' subjects
- teachers' and career advisers' assumptions about appropriate careers for girls

Schools and local authorities adopted policies to encourage girls to choose mathematics and science subjects. At a national level, the UK Equal Opportunities Commission (EOC) funded targeted projects to devise ways of presenting science in ways that were interesting to girls. For example Girls into Science and Technology GIST and women engineers visiting schools VISTA. GIST ran over three years and tracked two thousand Manchester school girls investigating their attitudes to science whilst trying to change them to be more favourable. Evaluations of these initiatives is scant, but those that exist point out the short-term, local nature of the intervention and hence their limited lasting impact (Whyte 1986).

The ambitions of these initiatives lived on in the activities of a number of organisations which were established at the same time. The Engineering Council (an umbrella body for professional engineering bodies) funded Women into Science and Engineering WISE. The Department for Trade and Industry set up the Promoting Women into Science, Engineering and Technology Unit (www.set4women.gov.uk), both of which structures continue to operate seeking to enthuse girls about SET subjects. WiTEC - Women in Science, Engineering and Technology was formed as a network in 1988 and after more than ten years of networking and project activities related to women and SET, established itself as a non-profit making European association in May

2001. Again with a paucity of evaluation evidence of activities where conflicting factors make establishing cause and effect notoriously difficult (Clarke 1999) it is impossible to conclude whether subsequent increases in female qualification levels or university entry in some science subjects is due to their activities.

Figure 2: Elements of Position 1 Recognition of SETs' economic contribution and the need to attract more scientists

Policy demand	**Barriers to overcome**	**Actions adopted**
- More skilled workers	**- Enthuse girls**	**- Targeted programmes** **- Infrastructure to promote**
Assumptions:	Explanation:	
No gender differences	Gender socialisation	GIST
Science is neutral	Poor careers advice	VISTA
Human capital necessary for economic growth	Image of science	

Critique of Position 1

Challenges to the policies and activities first funded in the 1980s have focused on the assumptions which underpin them rather than the structure of the activities themselves or the premise that more women are needed in scientific disciplines. These challenges have been made by academics working in the fields of science and social science.

First, they focus on the seemingly egalitarian notion that the economy needs qualified scientists of either sex. This notion encapsulates an instrumental view of women's labour as a resource to be activated, and can be interpreted in Marxian terms as a low valued 'reserve army of labour' to be drawn in (and by implication discarded) as and when the capital economy requires. Henwood (1998) has argued that the needs of industry have over shadowed arguments for social justice and the search for explanations of why women are under-represented which go beyond reasons of human capital. This has served to maintain the focus of attention on women's 'deficiencies' in terms of their qualifications, and to direct action towards issues of entry and recruitment. Only in the 1990s did the 'untapped pool' policy cast its net wider to consider the attrition of women from SET careers and strategies for attracting women to *re-enter* science.

Second, academics have critiqued the simplistic and 'popular' explanations for girls' lack of interest in science. Irwin and Wynne (1996) refute the public's ignorance about science. Rose (1994), Henwood (1996) and Spanier (1995) observed that the public's negative impressions go beyond scientific processes and include a rejection of its application and apparent lack of social responsibility (for example in the technological development of weaponry and warfare) (Shepherd 1993). Others began to contest the content of the science curriculum as 'gender blind' and the blame the 'abstract' representation of scientific ideas for being unappealing to young women (Keller 1985, Rose 1994). These critiques were the forerunners of more fundamental challenges to the neutrality and objective nature of science practice and knowledge which gathered momentum in the 1990s. Finally these explanations were criticised for putting the onus on girls and young women to change their views leaving the behaviour of the establishment unquestioned.

Recognition of the 'female condition' and the need to level the playing field (Position 2)

Alongside European Union EU and national concerns about the economic development of member states ran a desire for the effective integration and inclusion of all Europe's citizens. The history of the EU's equality policy has been described elsewhere (Booth and Bennett

2002). It came to be enacted throughout the 1970s and 1980s as individual women sought rulings from the European Court of Justice on conditions and treatment at work and equal pay. The 'equal treatment' perspective which emerged, is located in a Liberal Feminist tradition, upholding concepts of reason, law, freedom and rights first expressed by 19th century classic theorists associated with J.S. Mill and de Tocqueville, with its focus on the individual and individualism.

This perspective prompted questions about discriminatory practices, equality of access to opportunities and the fairness of procedures. There emerged:

- A clearer definition in European law of discrimination that described unfair treatment arising from gendered prejudice, arising through deliberate or unintentional action (direct and indirect discrimination).
- Legislation to minimise the way in which the 'female condition' – in regard to pregnancy, maternity and child-rearing – impact on women's chances of securing an equal place with men in the world (e.g. Directive on the protection of pregnant women at work 92/85/EEC Oct 1992).
- Successful campaigns leading to the introduction of a series of European Directives binding member states to institute changes through their national legislative frameworks to ensure the equal treatment of women in the workplace, equal access to education and training and the establishment of fair practices in the provision of goods and services, including property, financial, taxation.

These legislative developments were accompanied by the aspiration that more women would enter and progress in the scientific labour market until a 'critical mass' was reached (estimated to be 35% of the total) where women were present in sufficient numbers to permanently and incrementally change the structures, systems and practices everyone was operating in (Kanter 1977, Martin 1998, Norris and Lovenduski 2008).

Developments in gender equality legislation in turn influenced and informed the policies relating to women in SET. Two major policy strands in the mid 1990s which attempted to level the playing field for women were developed in the Higher Education sector. To address the issue of retention in academic employment the Committee of Vice-Chancellors and Principals with the government funded research councils agreed to improve the rights of contract researchers under the Research Careers Initiative (RCI). Part of this agreement was that additional funding would be supplied to provide substitute cover should a female researcher become pregnant in order to allow maternity leave to take place and give women a measure of career continuity. The RCI also put in place measures to improve appraisal, training and career guidance opportunities for women. In 1999, Lord Sainsbury Minister for Science and Sir Robert May, Chief Scientific Advisor to the government, endorsed a high profile initiative called The Athena Project. This project was another product of the Vice-Chancellors' and Principals' group with an agenda to remove barriers which discriminated against women and to significantly increase the numbers of women in top positions in the academe by 2007. The project's main activity has been to fund a series of mentoring and staff development projects in individual institutions focusing on issues of career advancement and women returners.

In the late 1990s, the major trade unions associated with scientific employment came together to launch the Science Alliance Charter calling for the commitment of senior management in the private and public organisations to a range of principles:

- Equal pay on appointment and throughout women's and men's careers
- Transparency in the judgements of research results and research applications
- Openness in peer review systems
- Flexible employment policies to allow the combination of work and domestic life
- Improved maternity and paternity leave
- Access to high quality, affordable childcare
- Development of anti-discrimination and harassment procedures
- Effective monitoring towards these goals

These type of policy initiatives raised new expectations for organisations and companies to put in place internal equal opportunities policies and to raise awareness among their workforces,

particularly their managers, about the ways in which gender stereotypes can influence decisions and actions resulting in negative outcomes for and discrimination of women.

As an adjunct to the government's White Paper 'Realising Our Potential', the 'Rising Tide Report' was prepared by a group of women scientists and published 1994 (Engineering and Technology Committee on Women in Science 1994). It implicitly shifts the debate on from women in science as an 'untapped pool of labour' to the argument that investments in human capital, which are costly to both the individual and the government, should bring returns: It raises the issue of women's advancement in professional science and in particular that women's greater responsibility for families and childcare/care is not recognised nor adequately compensated for. Its recommendations call for:

- companies to adopt equal opportunities policies
- schemes to be developed by the Department for Employment to support scientifically qualified women to return to careers in science
- that the 'female condition' be recognised through the provision of affordable childcare / tax incentives
- representation of women on SET advisory bodies to be increased

The House of Commons Select Committee on Science and Technology reviewed the progress of the 'Realising Our Potential' White Paper in 2000 and the Chief Scientific Advisor told the committee that most of the recommendations made in the report had been implemented though noted that under-representation of women at all levels continued.

An important contribution to this phase of the political debate was Sue Berryman's book *Who will do science? Minority and Female attainment of science and mathematics degrees: Trends and Causes* (1983) and its subsequent application to UK experience. Berryman introduced the 'pipeline model', based on an empirical analysis of gender differences across the entire process of becoming a scientist rather than on discrete educational and career stages. By conceptualising the scientific career as the sections of a pipeline, this model concisely and visually describes where leakages occur and the volume decreases leading to shortages in supply. It prompts questions about the quantity of women travelling down the pipeline and the slow speed of their progress along it, neatly capturing the political concerns about women's entry rates and the emerging focus on their progression. It prompted an analysis of where the points of greatest 'leakage' were, supporting the arguments that the point at which women were exiting scientific careers coincided with their greater family responsibilities (Rees 2001).

Theories about women's labour market participation in other fields reinforced the explanations suggested by the pipeline model. For example Catherine Hakim (2000) put forward her influential 'Preference Theory' which claims that it is women's own choices about their employment and lifestyles which is the key source of their under-achievement in their careers and accounts for most of the differences in women's and men's labour market outcomes. The theory proposes that groups of women give paid employment different priority and categorises them into three distinct groups:

- 'adaptive women' - non-career orientated women who wish to combine work and family or who have un-planned careers
- 'work-centred women' for whom employment is their main priority
- 'home-centred women' at the other end of the spectrum who make family their central and only preoccupation.

Findings that women who reach the top of their profession are often childless, and that the majority of women with children who return to SET careers work part-time (Glover 2001) appear to be explained by the argument that this is their preferred choice, guided by essential gender roles.

Figure 3: Elements of Position 2 Recognition of the 'female condition' and the need to level the playing field

Policy demand	Barriers to overcome	Actions adopted
- Remove sex discrimination embedded in policies and practices **- More women at the top**	**- Discriminatory practices** **- Retention of women**	**-Compensate women's caring role** **- Introduce equal opportunities policies**
Assumptions:	Explanation:	
Biological differences and gendered socialisation give rise to gendered preferences Science is neutral	Attrition at point women have children Gender stereotypes produce discrimination Pipeline model	Mentors and role models Better maternity / paternity leave and cover Develop equal opportunities policies

Critique of position 2

Again the critique of this position comes from within the academic community of science and social science. The 'equal treatment perspective' has been criticised for proposing a short term fix rather than permanent and radical change. Although the perspective throws attention for the first time on *organisations* it implies acceptance of their existing norms and standards, requesting the addition of equal opportunities commitments and special treatment for women to bring them up to the same position as men, rather than challenging that privileged position. It has also been accused of advancing the concerns of white, western, middle class women who are best placed to take advantage of the helping hand to advance.

The earlier work of Haraway (1988), and Harding (1986) resonates here as they argue that because the SET community is homogeneous its context cannot be neutral; masculine values, practices and cultures simply go unrecognised. In the early 1990s, picking up the theme of discrimination in organisations, research provides evidence of male hostility towards women's presence in SET (Carter and Kirkup 1989, Cockburn 1985a, Hacker 1981, Kirkup and Smith Keller 1992, Wajcman 1991, Evetts 1993a, EOC 2004 Bagilhole et al 1997, Roberts and Ayre 2002) and women's strategies for 'coping' with marginalisation, harassment and closed career paths (Devine 1992, Spanier 1995). These critiques form the basis of the next position.

The central focus on women's family preferences as an explanation for their absence from science career trajectories and the formulation of these trajectories as a linear 'pipeline' have been challenged. Evidence of women's commitment to paid work and patterns of exit and re-entry have been demonstrated. The result is a more complex and messy picture of women's labour market engagement which holds implications for the way researchers study it, policy makers design interventions, and organisations act to bring about change. (This critique is discussed in more detail in Section 5.2 Vertical Segregation).

Recognition of scientific gender bias and the need to re-examine norms and values (Position 3)

Critiques of the previous positions provide a body of evidence to problematise science itself; supporting a contention that SET incorporates male values, practices and theories because of its history, practitioners and locations. Rather than women being deficient and choosing not to take up the opportunities on offer to fulfil their potential in science, they are under-represented because of an unrecognised inherent bias in the social construction of SET environments.

This position draws on both a radical feminist tradition and post-modern theory. Radical Feminism emerged in academia in the 1960s raising new questions about the ways in which reproduction, sexuality, and male violence against women give men power over women's lives. Pre-dating capitalism, the system of 'patriarchy' oppressed women and recommended to

women their separation from men to escape male dominance, in order to create new women-centred ways of knowledge production, research methodologies and working arrangements. This in turn began the development of feminist methodological approaches. Post-modernism has posed many changes to the binary dualisms set up by liberal and radical feminism. It has challenged the usefulness of conceptual categories such as 'gender' and 'capitalism', arguing instead that social reality is fragmented (Bradley1996) and incapable of simple categorisation; and more fundamentally that social reality is socially rather than objectively created, hung together on dominant discourses, and non-objective norms. Prompted by the massive changes in technology and communication connecting peoples and altering daily lives on a scale not witnessed since the industrial revolution, post-modernism contends that there is no merit or possibility of investigating women's oppression as a group, only as individuals.

In the mid 1980s Harding (1986) was one of the first theorists to apply Feminist Standpoint Epistemology to women's experience in SET. This perspective argues that there is no one position from which knowledge can be developed, there are multiple standpoints, and some are better than others in terms of their commitment to social justice. Women's standpoint in SET has been assumed by some to be essentially different from that of men following their experience of being subjugated. These developments have prompted renewed scrutiny of the SET curriculum and pedagogical approaches and their impact on young women. It has also intensified attention on organisational practices, particularly the implementation of equal opportunities policies, with a greater awareness of the influence of cultural norms and gendered stereotypes on decision-making.

Policy arising from this position has largely been confined to the Higher Education sector. Although there is little evidence that key stakeholders are embracing questions about scientific subjectivity (except in the areas of teaching and learning practice), national gender equality legislation, in compliance with European Union membership has renewed and increased attention on organisational practices and procedures. The UK Equality Act 2006 imposes a requirement or 'public duty' on all public institutions to promote gender equality in order to demonstrate that discrimination is not taking place (in recruitment, promotion and appraisal processes) and that in areas where women or men are under-represented, barriers are being tackled, for example though gender awareness training for staff or targeted funding or support services. This requirement aims to make gender equality the responsibility of every member of an organisation, to 'mainstream' it into the common culture and values (Rees 1998).

Figure 4: Elements of Position 3. Recognition of scientific gender bias and the need to re-examine norms and values

Policy demand	Barriers to overcome	Actions adopted
- Identify and challenge the normalisation of male values, ideas and material advantages	**- Change hearts and minds** **- Make up for women's past subjugation**	**- Mainstreaming gender equality** **- Women only resources**
Assumptions:	Explanation:	
Male bias part of reason for under-representation of women Science is subjective, norms and values are masculine	Transformation of culture required Examine all policies and practices including knowledge production and teaching	Gender awareness training for staff New teaching methods / content devised

Current political debates: where next?

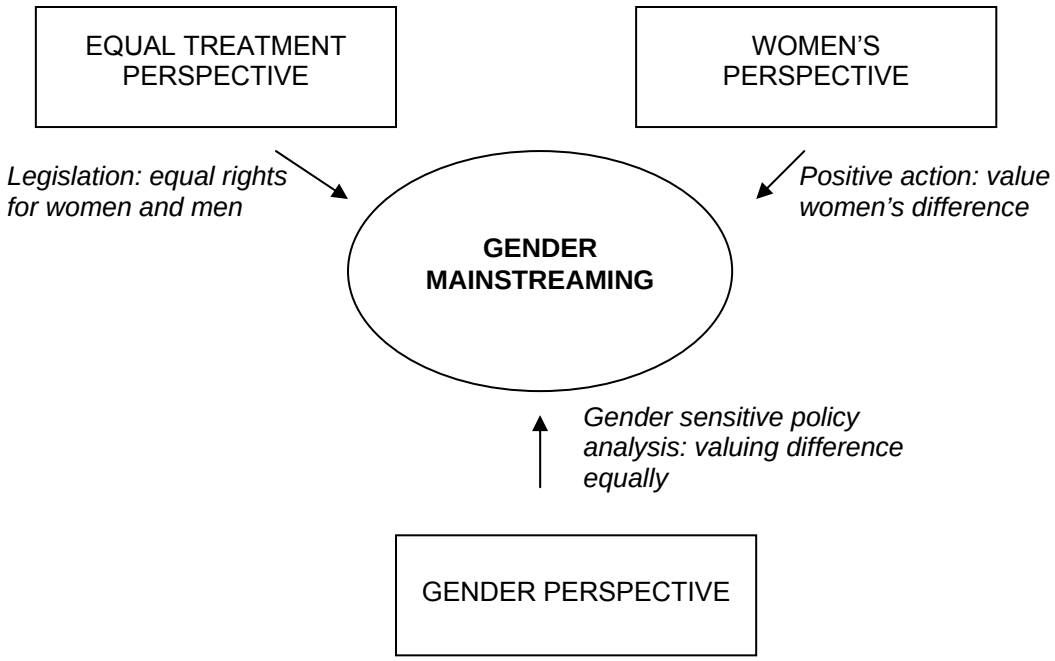
The political debate on gender and science and the resulting policy interventions to address perceived imbalances has taken place in the wider context of the national legislative and policy approach to gender equality. This context can be simplified into three overlapping and interdependent areas which are useful in conceptualising where the political debate is going in the future.

While the UK can describe the development of its equality practice in a linear way, Ireland and many other states cannot. A holistic view of the different equality perspectives is useful in explaining the contemporary experience, it also allows us to move away from labelling perspectives and approaches as 'old' and 'new' since academics have argued that all have a useful contribution to make. Booth and Bennett (2002) introduced the idea of a 'three legged stool'. With this model it becomes possible to recognise that progress in the field of equality is dependent on three important supports, and that if any one is under developed the 'stool' or outcome will 'wobble'. The three perspectives are:

- '*equal treatment perspective'* describing actions which attempt to guarantee women and men the same opportunities in the public sphere. Its main way of delivery is through statutory and mandatory legal instruments and policies.
- '*women's perspective'* inspires initiatives that recognise women as a disadvantaged group who deserve and require special provision in order to rectify their past experience of discrimination which has become institutionalised and to unleash their suppressed contribution to public life and thinking.
- *'gender perspective'* promotes actions what aim to transform the organisation of society to effect a fair distribution of human responsibilities. It acknowledges differences between women and men and it is premised on an understanding that men are not deliberate or universal oppressors of women but are governed by cultures and norms which both constrain and advance them. The gender perspective is delivered through new tools which demand gender-aware policy-making and scrutiny of all organisational practices, values and norms.

Mainstreaming gender equality can be positioned in the middle of the diagram, it is the culmination of all three perspectives and will reflect the peculiarities of national equality histories in striving to change hearts and minds to form a new set of social gender relations.

Figure 5: The equality stool reproduced from Booth and Bennett (2002:435)



With the three legged stool in mind, it is possible to assess the current political debates more candidly. Certain assumptions and types of initiatives persist from Positions 1and 2, in fact in the UK they still predominate. However, the model prevents us from labelling this as backward looking and instead demonstrates that these initiatives still have a contribution to make in moving women in science forward and in achieving a gender balance.

Policies concerned with increasing the quantity and quality of the scientific labour supply still prevail, and have intensified with concerns about economic growth becoming more pressing in the recessionary context. The late 1990s and 2000s have seen a continuation of government reports and White Papers along with new funding streams supporting innovation in SET and commercialisation activities. A further trend in this area of policy development has been a retreat from the focus on only women. The lack of take up of science in schools by boys and a falling number of male university entrants, particularly in physics, has broadened the focus to gender (Glover 2001:75). Although this is welcome, attention on women's particular disadvantage continues in other policy areas for example, the area of scientific excellence. An important initiative in this area in the UK has been implementation of compensation criteria in the latest Research Assessment Exercise and in the adoption of the notion of 'academic age' rather than 'chronological age' when assessing the research output of academics (a key measure for promotion). Academic age is designed to ensure that career breaks due to family or caring responsibilities do not count against individuals. In 2002 the Secretary for State for Trade and Industry, Patricia Hewitt (a vocal supporter of women's rights) commissioned the 'Greenfield Report' on the barriers to women in SET, in particular looking at women's vertical segregation in both private and public sectors. This report recommended the establishment of a national resource centre to support women in SET – the UKRC. The table below summarises the main of the policy milestones of the last three decades.

Figure 6: UK Policy interventions, Women and SET, 1980-2004

Date	Political Intervention	Description
1980	Finniston Report	Focus on recruiting girls in science education to widen the talent pool
1984	Year of Women into Science and Engineering	Sponsored by the Equal Opportunities Commission and Engineering Council
1990	Responsibility for Women and SET assigned to the Department for Trade and Industry	Shift away from recruitment to science education to increasing the number of female SET professionals / skills in the labour market
1993	Office of Science and Technology in the Department for Trade and Industry, White Paper '*Realising Our Potential'*	Committee of women in SET commissioned to produce '*The Rising Tide'.* This report recommended a dedicated unit to promote women in SET based in the Office of Science and Technology
1994	Unit Promoting SET for Women in the Office of Science and Technology established	Launched the *Athena Project* focusing on female science academics.
1994	*'The Rising Tide: Report on Women in Science, Engineering and Technology'*	Government response *'Women Science, Engineering and Technology'* published in the same year.
1995	Action Plan for Gender Equality in the Building Professions	Produced by the Chartered Institute of Building / Department of the Environment
2002	Office for Science and Technology commissioned Baroness Greenfield to report on women and SET	*'Set Fair Report'* was the basis for the '*National strategy for women in SET'* in 2003. Key recommendation to establish a national centre.
2004	UKRC – UK Resource Centre for Women in Science Technology and Engineering established in Bradford, a partnership of 6 Universities.	National lead organisation for the provision of advice, services and policy consultation regarding the under-representation of women in science, engineering, technology and the built environment (SET).
2004	*General Formal Investigation into Occupational Segregation and Apprenticeships*	Conducted by the Equal Opportunities Commission, the investigation looked at the degree of segregation by gender and identified good practice promoting diversity in apprenticeships.

An important aspect of the development of the political debate about women and SET in the UK has been the existence of a dynamic movement of women in manual trades. In the 1970s, grass roots feminists campaigned at local level for women's access to vocational training (for craft skills outside the apprenticeship system) provided by further education colleges, using the 1975 Sex Discrimination Act as their lever. The Manpower Services Commission (a non-department body of the Department of Employment) took up the issue in the 1980s funding the 'Wider Opportunities for Women programme' (WOW) delivered by universities and colleges. Simultaneously, the report 'Balancing the Equation' was produced for the further education sector providing suggestions to colleges on how to improve women's participation on all non-traditional courses. Left wing controlled Local Authorities in London established a precedent for

positive action through their model of Direct Labour Organisations to deliver their construction, and building maintenance needs by recruiting and training local labour, with a quota of female participants. Trades bodies and boards began recognise the demand for equality of opportunity and in 1982 the Union of Construction, Allied Trades and Technicians UCATT was one of the first bodies to form a Women in Construction Advisory Group. In the 1990s women's issues were kept on the agenda of the construction industry by concerns about skills shortages; captured by the 'Latham Report' commissioned by the Construction Industry Board in 1994 which put forward a business case for women's increased participation in manual trades. Women in the manual trades' movement have overlaps with women with in the science academy since in a number of universities courses in the former have been explicitly linked to foundation qualifications in universities to provide those women who want them with progression routes into higher paid professional work. The UKRC encapsulates the perspectives of both groups because of the universities involved in running the centre and the individuals within them, many of whom entered SET via the trade route. Whilst there are many accounts of the initiatives undertaken to support women into manual trades produced by individual projects, there is very little academic analysis of their reception by industry or their wider impact on the culture and practices of trade organisations and employers. The Equal Opportunities Commission's 'General Formal Investigation into Occupational Segregation and Apprenticeships' conducted in 2004 is one notable exception.

2.3 Trends in political debates on gender and science in Ireland

As outlined in the introduction, Ireland's economic structures and women's participation in the labour force are nascent and still developing. There has not been the same quantity of government policy development and academic analysis as in the UK. However, Ireland has one advantage, it has been able to learn from trends in the UK, leap-frogging phases in the policy development process described above. In the 1990s Irish policy initiatives began to reflect all three positions simultaneously, and in particular Ireland has a greater governmental emphasis on the 'gender perspective' with a number of high profile initiatives aiming to mainstream gender equality.

The initiatives outlined in the diagram below commenced in the late 1990s and are ongoing. Little research describing their operation or evaluation of their impact as yet exists. They fall under each of the three positions already described and reflect the associated assumptions. Four key stakeholders have been involved their design and delivery, these are all governmental departments or statutory bodies:

- Department of Education and Science DES with its statutory body Higher Education Authority HEA
- Department for Justice, Equality and Law Reform
- Department for Enterprise, Trade and Employment DETE

Each is responsible for taking 'positive action to increase the participation of women and to gender mainstream science, technology and research in Ireland' (Allan 2001:4)

The initiatives taken up by the Department of Education and Skills DES, which directly address women and science, fall under the heading of increasing the number of girls taking science subjects at school. Responding to a national concern that science was absent from primary level education (age 4-12) (Allan 2001) the 'Science, Technology and Gender: Primary Schools Action Research Project' was piloted in 2000, aiming to devise classroom materials for teachers to deliver 'gender-fair' scientific/ technological education. A further project aimed to increase the participation of girls at secondary level; in 1999 the Physical Science Initiative supported the provision of modern laboratories and a career development programme for teachers. The Intervention Projects in Physics and Chemistry which sat along this investment gave extra support to schools that did not have SET subjects on the curriculum as well as those that did, who were committed to reduce the gender imbalance in take-up rates. As a result the percentage of girls taking chemistry has begun to exceed that of boys in these schools (Allan 2001).

Figure 7: Elements of all 3 Positions in Ireland

Policy demand	Barriers to overcome	Actions adopted
Position1 **- More skilled workers**	**-Enthuse girls**	**-Targeted programmes** **- Infrastructure to promote general entry** Department of Education Programmes: - Primary curriculum - Laboratory facilities - Girls secondary school access
Position2 **- Remove discrimination** **- More women at the top**	**- Discriminatory practices** **- Retention of women**	**- Compensate women's caring role** **- Introduce equal opportunities policies** Higher Education Authority - EO policies in sector - Mature student entry routes
Position3 **- Tackle male bias**	**- Change hearts and minds** **- Make up for women's past subjugation**	**- Mainstreaming gender equality** **- Women only resources** *National Development Plan* - Promoting gender mainstreaming - Gender proofing *Women in Technology & Science WITS* - Women's advancements and organisational practices

The Higher Education Authority HEA focused its efforts on institutional practices, commencing a statutory review of all equality policies in the sector guided by the spirit of the 1997 University Act. This act requires all universities 'to promote gender balance and equality of opportunity among student and employees of the university' as well as 'to facilitate lifelong learning through the provision of adult continuing education' (Allan 2001). The HEA also administers funds to universities via the Targeted Initiative Scheme which includes support for mature student access, focusing specifically on higher education for women (although this funding is available for students in all disciplines.)

Operating outside the government infrastructure, are a number of key projects and networks. Women in Technology and Science (WITS) was inaugurated in November 1990 to actively promote women in science in Ireland. It has members from a broad range of scientific, engineering and technological backgrounds including teachers, computer experts, technicians and journalists working at all levels. EU EMPLOYMENT - NOW funding has played an important part in developing a raft of local initiatives in both the education and the professional sphere, for example girls into engineering taster days, and role models for professional women provided by a European database of women experts.

Ireland has gone further than the UK in its commitments to mainstream gender equality (Position 3). The Department of Justice, Equality and Law Reform DJELR has responsibility for maintaining and enhancing equality for all groups in Irish society. It manages the 'National Development Plan NDP', a five year plan which outlines significant investment and is underpinned by a gender mainstreaming. The plan covers structural development, education and training, productive sector and social inclusion. Only five of its 130 measures are exempt from a consideration of gender equality. Under the Regional Operations Programmes of the NDP is the Equality for Women Measure (£23.4m 2000-2006). It included projects to support women in SET, for example the development of a one-year foundation outreach access course in science maths and technology to improve women's access to university degree routes in science and technology.

The statutory stakeholders have established units with responsibility to advise and monitor progress towards the governmental objective of mainstreaming equality (DJELR EO and Social Inclusion Co-ordination Committee (oversees the NDP), DES Equality Unit, HEA Higher Education Equality Unit). Ireland received considerable EU funding in the late 1990s which supported two further projects aimed at improving women's educational prospects and qualifications. As part of one of these programme EMPLOYMENT – NOW programme, FÁS the national training and skills body (an agency of DETE) undertook a pilot project to gender proof (look for unintended gender bias) the systems, procedures and practices within selected areas under its own remit, and where deficiencies were identified to implement change. This proofing exercise covered the operations of a significant proportion of the productive sectors' statutory bodies such as Enterprise Ireland, IDA Ireland (grants and R&D funding) Teagasc (Agricultural research), Coford (forestry research and research training) the Marine Institute (research funding) and the HEA.

The next section introduces the literature of the Gender and Science Database GSD and indicates how it supports the positions identified here.

3. Horizontal and vertical segregation in scientific careers: main trends from 1980-2007

The division of labour market opportunities into men's jobs and women's jobs (horizontal segregation) and the absence of women from senior level decision making in organisations, (vertical segregation) has come under increasing scrutiny by policy makers, outlined in the previous section. Reviewing the GSD publications from the standpoint of segregation we can see that in most cases the issues of horizontal and vertical segregation have been dealt with separately. The former has been discussed in relation to concerns about the lack of women (and men) entering scientific occupations and the later has been the focus of analysis about women's progression within a gendered hierarchy. This separation has produced a useful analysis of the situation over the last thirty years, but it has also obscured issues which may be relevant to the explanation of segregation, and benefit from practical intervention. This section outlines the main trends in the explanation of segregation and includes a brief discussion of areas which may have been overlooked.

The explanation of horizontal segregation in science has centred on education. As Section 5.3 Stereotypes and Identities elaborates, there is a considerable body of literature which attempts to define the sex-role stereotypes and their influence on young people. Research has linked these stereotypes to young people's belief in their cognitive strengths, their learning styles, subject preferences, their perception of science as an appropriate job. The practices and prejudices of teachers, parents and peers have been examined to understand better the structures and contexts which contribute to this process of gendered socialisation (the individual's internalisation of sex-stereotypes). The assumption made here is that the way into a science job is via the qualifications route and hence an important way of increasing the numbers of entrants into the scientific labour pool is to transform the stereotypes which deter people. This assumption most closely accords with Position 1 (the need to increase the number of scientists) but more recently it has recognised the need to change the organisational approaches of school, colleges and universities to implement equality of opportunity (Position 2) and to challenge gendered essentialism in the curriculum and the way it is taught (Position 3). Issues which have been overlooked include the alternative routes into science careers, from other allied disciplines, or a manual training about whose entrants we know very little. Another aspect of horizontal segregation which has only recently become apparent is clustering, as women begin to move through to the more senior ranks of certain science disciplines: The concentration of women into particular occupations or science specialisms about which there is anecdotal evidence but an absence of robust research.

Vertical segregation is better served by the GSD publications. There is a very developed literature about what happens to women in science jobs in science workplaces and hence why they exit early or fail to progress to senior level. Section 5.3 Stereotypes and Identity contributes an explanation of the use of gender stereotypes in the workplace, for what purposes and to what ends. Section 5.4 Science as a Labour Activity outlines the 'pipeline model' of women's career progression, identifying women's career choices and constraints as they attempt to negotiate work life balance and the sexual division of labour. SET's dominant masculine culture provides one dimension of the context they are operating in. This culture upholds a definition of the 'ideal SET employee' as one who leads a male lifestyle (without caring commitments) with a male physiology. The study of scientific excellence in Section 5.6 has assessed the ways in which excellence is defined and assigned, by whom, producing gendered advantages in pay and promotion. Explanations of vertical segregation broadly fit into Position 2, characterised by a concern with the unfair practices of organisations. Very recent literature in the field of engineering has adopted Position 3 and is leading the way in research into the existence of a pervasive gendered sub-text which unconsciously influences all actors.

Some bodies of literature provide a contextual explanation for both horizontal and vertical segregation, these are the papers reviewed in Section 5.7 Gender in Research Contents which challenge the maleness of scientific epistemology and ontology arising from the situated knowledge of a homogeneous community of contributors and the analysis and critique of policy design and ideology discussed in Section 5.8 Policies towards gender equity in science.

4. Main trends on research on gender and science from 1980-2007

The discussion of the trends in the political debate about women and science in the UK and Ireland has established that early attention has been focused on the qualification and recruitment of women into science. Research into female retention and advancement has developed over the last decade. These elements of the debate about women's under-representation are conceptually different, giving rise to different types of policy intervention in the three positions outlined. The implication for setting a research agenda is that they also have different data requirements and use different sources of information. For example, the issue of women's retention raised by the 'pipeline model' of women's scientific careers requires longitudinal data to track career trajectories, whilst an examination of advancement in the context of masculine organisational cultures requires data which can reveal different dimensions of vertical segregation including hierarchical distinctions between different grades of employment as well as personal perceptions of barriers and organisational values.

The diagrams which follow outline the basic data and methodological differences which relate to each of the main 3 positions raised by the political debate of gender and science in the UK (Section 2). They are not intended to be exhaustive.

- In the 1980s (Figure 8), attention was focused on the need to attract more individuals into science, and so research was directed towards science education as the (assumed only) path into scientific work. Data on girls' and boys' subject choices, academic achievement and progression began to be analysed by public stakeholders such as the government, local education authorities, colleges and universities. The tracking of student numbers and attainment was done quantitatively across the sector nationally and European comparisons undertaken. Quantifying and describing the problem is more prominent in the literature than analysis to explain the gendered trends observed which went no further than processes of gendered socialisation, described in small scale qualitative studies.

- A decade later the concept of the occupational pipeline dominated the discussion of segregation (Figure 9). Recognition of women's disadvantage in the scientific labour force arising from the demands of motherhood shifted the focus of research onto the proportion of women at senior levels in science and organisational responses. The source of data changed to national employment statistics and the records of professional bodies and individual institutions. Women's experiences of employment began to be examined to support the contention that women were choosing motherhood over career, or finding it impossible logistically and economically to support the two simultaneously. The equal opportunity policies of organisations were described and contrasted, although very little evaluation of their impact has been undertaken.

- Case studies, qualitative interviewing and textual analysis became more prominent from 2000 (Figure 10) as more questions were asked about women's motivations and choices. Re-examination of norms and values to identify insidious gender bias required qualitative approaches. These studies tended to be conducted institutionally or departmentally due to resource restrictions. Interest in gendered norms has promoted researchers to examine all organisational processes, including assessment, recruitment and appraisal processes.

Figure 8: Research Approaches - Recognition of SETs' economic contribution and the need to attract more scientists (Position1)

<table>
<tr><th>Focus (by sex)</th><th>Level of Analysis</th><th>Data sources</th><th>Methodologies</th><th>Limitations</th></tr>
<tr><td colspan="5">Recognition of SETs economic contribution and the need to attract more scientists</td></tr>
<tr><td>Selection of SET subjects at schools – GCSE, A level</td><td rowspan="10">National / EU comparative

Regional

Local Authority area

Institutional</td><td>Government departments for education and universities;
Local education administration structures</td><td rowspan="10">Quantitative:
▪ Sampling
▪ Micro-data
▪ Aggregated data
▪ Cross-sectional
▪ Longitudinal / cohort
▪ Descriptive
▪ Bivariate / multivariate analysis</td><td rowspan="10">Access to data due to potential disclosure: small numbers of records

Trends / comparisons: matching datasets as qualifications change

Gender blind data collection: analysis not gender disaggregated</td></tr>
<tr><td>Attainment in SET subjects at school – key stages, GCSE, A level</td></tr>
<tr><td>Transition to work based learning (trade) post 16</td><td>Local education administration structures;
Careers guidance services;
Trade bodies / employers</td></tr>
<tr><td>Transition to University</td><td>Government departments for education and universities</td></tr>
<tr><td>Selection of degree discipline</td><td>Government departments for education and universities;
National university structures for admissions and statistics</td></tr>
<tr><td>Degree attainment</td><td>National university statistics;
Higher education institutions</td></tr>
<tr><td>Destination on graduation</td><td>National university statistics;
Higher education institutions</td></tr>
<tr><td>Late SET qualification post 18, A level, degree</td><td>National sector skills bodies;
Labour Force Survey</td></tr>
<tr><td>Level of qualification of SET professionals in the labour force</td><td>Census of Population</td></tr>
<tr><td>Influences on choices of subject, all levels of qualification</td><td rowspan="2">Professional / trade bodies
Equality bodies
Government evaluation of promotional programmes;
Higher Education Institutions</td><td rowspan="2">Qualitative
▪ Interviews
▪ Case studies</td><td rowspan="2">Generalisation: small scale, contextually bound

Access to participants and ethical approval</td></tr>
<tr><td>Choice of destination post degree qualification</td><td>Institutional</td></tr>
</table>

Figure 9: Research Approaches - Recognition of the 'female condition' and the need to level the playing field (Position2)

<table>
<tr><th>Focus (by sex)</th><th>Level of Analysis</th><th>Data sources</th><th>Methodologies</th><th>Limitations</th></tr>
<tr><td>Demographic and labour market characteristics of scientists</td><td rowspan="2">National / EU comparative</td><td rowspan="2">Census of Population
Labour Force Survey
Annual Employment Survey
Academic studies in institutions
Professional bodies</td><td rowspan="11">Quantitative:
▪ Sampling
▪ Micro-data
▪ Aggregated data
▪ Cross-sectional
▪ Longitudinal / cohort
▪ Descriptive
▪ Bivariate / multivariate analysis

Qualitative
▪ Interviews
▪ Case studies</td><td rowspan="11">Level of geography restricted due to lack of disaggregation or disclosure

Generalisation: small scale, contextually bound

Access to participants and ethical approval</td></tr>
<tr><td>Number of women employed in SET industries / occupations</td></tr>
<tr><td>SET qualified women's economic status</td><td>Census of Population</td></tr>
<tr><td>Number of women at different levels in SET hierarchies</td><td>National</td><td>Census of Population
New Earnings Survey
Academic studies in institutions
Professional bodies</td></tr>
<tr><td>Clustering of women in certain SET occupational specialisms</td><td>National
Institutional</td><td>Census of Population
Academic studies in institutions
Professional bodies</td></tr>
<tr><td>Women's take up of career breaks</td><td rowspan="3">Institutional</td><td rowspan="3">Academic studies in institutions
Professional bodies</td></tr>
<tr><td>Women's use of flexible working</td></tr>
<tr><td>Women's career decisions – impact of children</td></tr>
<tr><td>Work life balance options in SET sectors</td><td>National
Institutional</td><td>Census of Population
Academic studies in institutions
Professional bodies</td></tr>
<tr><td>Women's representation on national SET bodies</td><td rowspan="2">National</td><td rowspan="2">Professional / Institution / Academic studies or reports</td></tr>
<tr><td>Institutions / Sectors with Equal Opportunities Policies</td></tr>
</table>

Figure 10: Research Approaches - Recognition of scientific gender bias and the need to re-examine norms and values (Position3)

Focus (by sex)	Level of Analysis	Data sources	Methodologies	Limitations
SET Organisational cultures and women's experiences Women's career trajectories Women's access/barriers to promotion New opportunities within emerging technologies sector Gendered pedagogical impacts Gendered nature of assessment systems in education Gendered nature of assessment systems in funding regimes Mainstreaming gender equality strategies and programmes	Regional / Institutional	Academic studies in institutions Professional bodies	Qualitative ▪ Interviews ▪ Case studies ▪ Documentary analysis	Lack of analysis across sectors Generalisation: small scale, contextually bound Access to participants and ethical approval

Data Issues

The figures above indicate that quantitative datasets may not be capable of answering all our questions. The size of the sample or cohort being studied may prevent access to the data since individuals' identities could potentially be disclosed from the resulting analysis. This is particularly the case in longitudinal datasets where a large amount of biographical information may be collected on a dwindling number of individuals and also in the use of Census micro-data, especially when the variable of ethnicity is used in the analysis. Establishing trends across three decades may also be compromised or prove impossible if the characteristics being tracked have been redefined (e.g. occupational category definitions) or in the real world (e.g. qualifications and their content can be altered to according to changes in government or employers' skills agendas).

In some cases data has not been collected by sex, or if it has, analysis is not gender disaggregated. Following a significant lobby in the 1990s in Europe, followed by legislation which strengthened the requirement of governments to report on gender equality progress this phenomenon is less prevalent than it was, though again can cause problems when establishing trends going back over time. These issues mostly affect large quantitative data sets. Quantitative data has other draw backs, that whilst it may be possible to accurately pinpoint the transition rate of scientific graduates' entry into scientific employment in any one year, it cannot explain why the rate is low or lower than the year before. For this qualitative data is needed. The methods of qualitative data collection involving very often face to face contact necessarily make this form of data collection time consuming and expensive, requiring specially trained research staff to conduct focus groups, interviews or observations. Consequently the majority of qualitative studies are small scale – and often for the important reason of triangulation of findings - institutionally bound. It is most often not possible to generalise from these findings to larger populations or cohorts. Qualitative data serves to provide new hypothesis which can be tested through larger scale quantitative work or real life stories which can be used to illustrate conceptual propositions.

The origin of the data source may be significant in an assessment of what the data in this area can or cannot tell us. Those funding gender and science research have their own agendas, outlined in Section 2.0 which, to a greater or lesser extent, guide the questions asked by researchers and in some cases the selection of findings made public which may limit the contribution of the work. Finally, many of the unanswered questions in the field of women and science pose a 'formidable investigative task' (Glover 1999:79). Shifting attention away from women's 'deficit' in qualifications and staying-power in scientific careers onto the role of scientific organisations in perpetuating women's under-representation will require sensitive yet extensive questions of taken for granted procedures, values and informal rules which have governed the practice of science since its institutional inception. Glover recommends that this research agenda can only be achieved by adopting a 'mainstreaming approach' (Rees 1998) which seeks through its actions to transform systems, structures and cultures winning 'hearts and minds' to the construction of a new set of social relations and working arrangements (EU 1999b:27).

Gender and Science Database Statistics on the Anglo Saxon Publications

Analysis of the Gender and Science Database GSD suggests that the type and quantity of research publications produced over the last three decades mirror the positions outlined in Section 2.

From the Gender and Science database it is possible to extract a description of the frequency of publications. Compared with all countries the Anglo-Saxon countries show a marked increase in research output after 1990. The majority of the literature problematises the current day situation, rather than taking a historical perspective.

	Average number of publications per year		Ratio ASCs/ACs
	Anglo-Saxon Cs	All Cs	
1980-1984	5.8	33.4	0.2
1985-1989	8.4	53.4	0.2
1990-1994	17.0	91.6	0.2
1995-1999	35.0	162.6	0.2
2000-2004	71.4	310.4	0.2
2005-2007	96.0	338.0	0.3
2008-2009	41.0	139.0	0.3

Source: Gender and Science Database GSD

The three most prominent topics explored by the literature in the database are that of women's entry and attitudes towards science (horizontal segregation 51.2% and stereotypes and identity 57.4%) and retention and advancement (vertical segregation 45.1%). Publications covering science as a labour activity are almost exclusively focused on the arrangements of work in relation to managing family commitments alongside a requirement for mobility and long hours and the scientific careers pipeline, than on organisational cultures which is a relatively new area of research. Similarly, publications exploring definitions of scientific excellence in the context of a challenge to the neutrality and objectivity of science disciplines, are under-represented.

	Topic analysed (%)		Ratio ASCs/ACs
	Anglo-Saxon Cs	All Cs	
Horizontal segregation	51.2	43.2	1.2
Vertical segregation	45.1	44.7	1.0
Pay and funding	17.4	12.6	1.4
Stereotypes and identity	57.4	54.0	1.1
Science as a labour activity	33.8	32.6	1.0
Scientific excellence	16.0	19.8	0.8
Gender in research contents	32.1	31.5	1.0
Policies towards gender equality in research	37.1	28.5	1.3

Cs – Countries ASCs – Anglo-Saxon Countries ACs – All Countries

Source: Gender and Science Database GSD

Analysis of the database by sector shows that 65.4% of all publications discuss the topics in relation to all the science sectors. Of the 34.6% which focus on specific sectors, the majority (83.1%) are concerned with developments in the Higher Education sector. The private non-profit and business / enterprise sectors make up only 2.5% and 18.3% respectively of single sector publications. This highlights an important gap. It may be explained by the difficultly of negotiating research access to private companies and organisations and the greater variety of research context represented by these sectors which span SMEs, medium and large/global organisations.

Institutional sector	Anglo-Saxon Cs (%)	All Cs (%)	Ratio AScs/Acs
All/General	65.4	48.8	1.3
Other	34.6	51.2	0.7
Total	100.0	100.0	1.0
Institutional sector - Other	**Anglo-Saxon Cs (%)**	**All Cs (%)**	**Ratio AScs/Acs**
Business enterprise sector	18.3	10.6	1.7
Government sector	25.1	26.0	1.0
Higher education sector	83.1	86.7	1.0
Private non-profit sector	2.5	3.4	0.7

Source: Gender and Science Database GSD

An examination of the literature by scientific field also shows an inconsistent coverage. Many research publications have highlighted the patchy representation of women across the different science disciplines, with the biological sciences attracting, though not retaining, greater numbers of young women on entry. Since much of the research has arisen from the interests of women working within science disciplines, this patchy representation has come to be reflected in the research output.

Scientific field	Anglo-Saxon Cs (%)	All Cs (%)	Ratio AScs/Acs
All/General	41.4	38.7	1.1
Other	58.6	61.3	1.0
Total	100.0	100.0	1.0
Scientific field - Other	**Anglo-Saxon Cs (%)**	**All Cs (%)**	**Ratio AScs/Acs**
Education	12.7	20.6	0.6
Humanities and arts	6.6	18.3	0.4
Science, mathematics and computing	49.4	46.6	1.1
Agriculture and veterinary	3.2	8.5	0.4
Health and social services	16.5	21.9	0.8
Engineering, manufacturing and construction	21.9	25.1	0.9
Social sciences, business and law	21.5	34.1	0.6
Services	0.5	0.7	0.7
Specific scientific discipline	**Anglo-Saxon Cs (%)**	**All Cs (%)**	**Ratio AScs/Acs**
No	54.2	72.8	0.7
Yes	45.8	27.2	1.7
Total	100.0	100.0	1.0

Source: Gender and Science Database GSD

Finally, it is possible to analyse the dominant research approaches used in the Angle-Saxon research. These are broadly in line with those applied in all countries, with the exception of qualitative research techniques which have been used more extensively to capture, compare and contrast (in some cases over time) the perceptions and experiences of female and male students and scientists.

Empirical research	Anglo-Saxon Cs (%)	All Cs (%)	Ratio AScs/Acs
Non empirical research	44.0	50.6	0.9
Empirical research. Quantitative techniques	17.7	17.9	1.0
Empirical research. Qualitative techniques	27.0	22.7	1.2
Empirical research. Quali-quantitative techniques	11.3	8.8	1.3
Total	100.0	100.0	1.0
Quantitative techniques	**Anglo-Saxon Cs (%)**	**All Cs (%)**	**Ratio AScs/Acs**
Representative sample	45.3	57.0	0.8
Micro-data	30.6	48.6	0.6
Longitudinal/cohort	9.8	8.2	1.2
Multivariate analysis	42.7	30.8	1.4
Qualitative techniques	**Anglo-Saxon Cs (%)**	**All Cs (%)**	**Ratio AScs/Acs**
Biographical research	8.4	17.6	0.5
Case studies	22.2	15.4	1.4
Content analysis	6.7	15.4	0.4
Interviews	63.3	64.8	1.0
Observations	21.2	15.2	1.4

Source: Gender and Science Database GSD

The report now considers the literature under different topics. Starting with horizontal and vertical segregation it reviews quantitative studies which aim to establish the nature of gender balance in science education and its occupations. Following this discussion, topics explaining how and why inequality arises are tackled. The aim of these discussions is to describe the literature which exists and to identify gaps in our knowledge.

5. Analysis by topics

5.1. Horizontal segregation

Key Issues

The literature of the GSD is primarily interested young people's gendered selection and attainment of SET academic qualifications at school and university, (and vocational training in FE colleges and work-based qualifications). These decisions go on to fashion the labour pool for the SET sectors (trade, industry and academia) and to uphold women's unequal presence. Under-representation of women in turn has given rise to misgivings about the validity of science pedagogy, image, and output.

Analysis of the GSD provides the following description of the literature on which this section is based.

Number and percentage of publications

	n	%
Ireland	126	41.2
United Kingdom	537	51.5
Anglo-Saxon CS	**542**	**51.2**
All Cs	**1,965**	**43.2**

Relation with other topics

	%
Horizontal segregation	100.0
Vertical segregation	53.9
Pay and funding	17.9
Stereotypes and identity	68.8
Science as a labour activity	37.8
Scientific excellence	17.7
Gender in research contents	24.7
Policies towards gender equality in research	39.7

Average number of publications per year

	Average
1980-1984	3.4
1985-1989	5.8
1990-1994	9.0
1995-1999	17.2
2000-2004	34.2
2005-2007	53.0
2008-2009	17.5

Methodological approach

Empirical research	%
Non empirical research	38.6
Empirical research. Quantitative techniques	21.0
Empirical research. Qualitative techniques	28.2
Empirical research. Quali-quantitative techniques	12.2
Total	100.0
Approach	**%**
Conceptual	36.0
State-of-the-art	36.3
Compilation of statistics	21.6
Building gender indicators	3.0
Empirical research. Quantitative techniques	33.2
Empirical research. Qualitative techniques	40.4

Empirical research techniques

Quantitative techniques	%
Representative sample	43.3
Micro-data	31.1
Longitudinal/cohort	12.2
Multivariate analysis	47.8
Qualitative techniques	**%**
Biographical research	7.8
Case studies	19.6
Content analysis	4.6
Interviews	69.9
Observations	21.9

Examination of GSD publications by 'life stage' illustrates the preoccupation with occupational careers and progression, particularly in the High Education sector.

Life course stage analysed

Life course stage	Anglo-Saxon Cs (%)	All Cs (%)	Ratio AScs/Acs
All/General	34.0	23.8	1.4
Other	66.0	76.2	0.9
Total	100.0	100.0	1.0
Life course stage -Other	**Anglo-Saxon Cs (%)**	**All Cs (%)**	**Ratio AScs/Acs**
ISCED 0	4.0	2.0	2.0
ISCED 1	9.9	6.8	1.5
ISCED 2	16.6	11.0	1.5
ISCED 3	17.0	13.8	1.2
ISCED 4	6.3	6.4	1.0
ISCED 5	26.6	36.2	0.7
ISCED 6	29.8	38.4	0.8
Early-career scientists	64.0	67.6	0.9
Mid-career scientists	60.9	62.8	1.0
Late-career scientists	57.6	59.4	1.0
Other	5.7	6.5	0.9

Research Questions

- How are women and men segregated by industry in the UK and Irish labour markets? How has this changed over time?
- What are the relative proportion of girls and boys choosing to study SET subjects at school / college/ university and their results, over time?
- Why does science education attract more boys? What deters girls?
- What is the attrition rate of women from professional SET careers? At which points in their careers paths does this occur?
- What initiatives have been undertaken to tackle horizontal segregation, in schools, colleges, university entry, academia and industry? Which have been effective?

Research Approaches

One of the leading UK scholars on gendered labour market segregation is Catherine Hakim who has looked at women's and men's participation in all occupations using the UK Census (Hakim 1994). As she has pointed out, sex based occupational segregation is a universal social phenomenon which has occurred across time and across different state labour markets, although with significant variations in the occupations 'naturally' assigned to women. These assignations can often be traced back to distinct sex-role expectations or concerns. The importance of her work has been to challenge popular generalisations about women's labour market participation, using statistical evidence, and to provide ways of conceptualising segregation which have acted as the starting point for further debate.

Her analysis of the 1891–1991 Census of Population explores the popular account that as more and more women have joined the labour market over the last century, the distinction of 'women's work' and 'men's work' dictating levels of occupational segregation has been diminishing. Her comparison of the Censuses revealed that there had been long term stability in women's work rate in the UK up until the 1970s when greater number of women began to take on paid employment. The explanation she favours for women's greater engagement at this time is the development of birth control and a fall in unplanned pregnancies which reduced the need for a physical separation of the sexes at work to control sexuality and maintain social order [drawing on Humphries 1987]. However, Hakim points out that although greater numbers of women were participating as paid employees, academic accounts of women's rising share of the workforce and their capitalisation of new jobs in the 'service' sector is misleading. She argues that women's share of paid employment has remained the same because no account has been made of their *falling* hours of work. In 1891 full-time work was the normal pattern of women's employment but by 1991 almost half of all women were working part-time hours. A calculation of women's contribution to the labour market on a FTE equivalent basis reveals that women's share of available paid positions in 1991 was 39% rather than the 43% commonly cited. The change that has taken place is a redistribution of working hours among a larger number of women rather than a great surge in the overall level of female economic activity. Hakim concludes that explanations of diminishing segregation cannot be pinned on rising economic activity rates.

Her further analysis does not contradict the perception that change has taken place in occupational segregation by sex. She charts the increase of 'mixed occupations' in which the male to female ratio approximately matches the average male to female ratio across all occupations. In 1991 this ratio was 6:4. Using this definition she has demonstrated that between 1891 – 1991 the number of mixed occupations rose from a fifth of all occupations to a third, with the proportion of male dominated and female dominated occupations accounting for another third each. She concluded that there has been a substantial drop in occupational segregation whilst recognising that this change has taken place incrementally over the whole century. The examples she gives of occupations in which a mix has been achieved include a high proportion

of professional and associate professional managerial occupations which were male dominated in 1891. Wider access to higher education and career paths requiring accredited expertise has assisted women's entry into these jobs. Hakim's analysis of manufacturing and science occupations shows there has been consistency in the sex ratio in a number of key sectors both old and new, these include: manual work in textiles, tanning, chemical, paper, plastics, printing metal working processes and agriculture have remained mixed occupations across the last century. Computer analysis and programming is a new sector which also falls into Hakim's mixed occupation category.

Hakim argues that female dominated sectors show the most change over the last century. At the turn of the century the majority of women's work opportunities were in domestic service, an extension of their role in the home, in an environment in which the absolute control of their daily lives by their father or husband was replaced by the oversight of an employer. In contrast female dominated sectors in 1991 bear no relation to domestic roles; clerical, sales, checkout and cashier jobs outnumber the number of jobs available in 'domestic' type roles such as childcare, catering and cleaning. Hakim concludes that the most important occupations for women are 'sex-neutral' rather than typically female jobs; they involve interaction with a diverse clientele in public locations rather than hidden away in the private sphere, she concludes that 'what is appropriate for women has changed'.

Hakim's explanation of why these occupations remain dominated by women and perceived as 'women's work' despite their essential 'gender neutrality' can be found in her theory of women's preference for family rather than work life (outlined on page 10). 'most women have actively colluded in their own imprisonment in unpaid work in the home and low-paid, low status jobs in the workforce' she claims (Hakim 1991:110). These occupations attract more women because they provide non-career jobs which fit around non-labour market activities, typically offering part-time working hours, low incidence of unsocial hours, short or casual job tenures. Hakim uses this same explanation for qualified women's lack of progress to senior levels of the professional hierarchy, they too want jobs which are subordinate to family commitments and so they choose less demanding and hence less well remunerated career trajectories to men.

Critiques of Hakim's conceptualisation of segregation from a gender and science perspective

Hakim's analysis has prompted considerable debate in the area of gender and science. Academics in the areas of organisational theory and post-structural analysis have engaged with her ideas their and since 1990s have produced new work relating to developments described in Positions 2 and 3:

- Hakim's proposition that there has been a decrease in sex segregation, shown by the increase in mixed occupations has been challenged. Research evidence suggests that the definition a 'mixed occupation' may be misleading. Burchell (1996) has argued that the complex interaction between occupation, sector (public / private) and size of employer has been overlooked and can produce pockets of segregation in occupations whose figures suggest a mixed sex composition. He observes that professional work in the public sector is a relatively new phenomenon and one which has provided opportunities for women who have been attracted by better family friendly terms and conditions of employment, the protection of unionisation and the commitment to equality of opportunity in recruitment and promotion. This is supported by research into medical professions which has identified female enclaves in dentistry and general practice and Burchell's own analysis of pharmacists. Within smaller employers in SET particularly in manufacturing companies women's relatively high participation in the sector can mask differentiation in their status and pay. Many more women are to be found in less skilled parts of the production/ fitting process, or confined to office based or packing roles. Burchell observes that again these jobs attract women because they are structured as secondary labour market-type employment (i.e. in reference to dual labour market theory which differentiates between primary full-time permanent employment to ensure the retention of skilled labour and secondary employment where hours and tenure are flexible and change according to the employers' need.)

- The second area of debate prompted by Hakim's analysis relates to her argument that women choose female dominated occupations or lower status / less demanding jobs to satisfy their greater orientation to home life than work life. Scholars working in the area of organisational theory have critiqued Hakim's 'Preference Theory' from both the demand and supply sides: From the demand side academics such as Grant et al (2006) have shown that among women in low paid low status work there is a high level of dissatisfaction and desire to progress. There is a significant second category of women who are 'treading water', accepting a less demanding job because the structure of opportunities available to them mean that there are no alternatives they can pursue until their commitment to home lives reduces (for example as children get older). In this case many women undertake privately funded study in preparation for progression. Interviews with employers show a blinkered approach to job design and a blanket assumption that all women want secondary employment.

  In the professional arena, Bennett et al (2006) have demonstrated a similar phenomenon among qualified women with caring responsibilities. Women assess whether they are able to take on the commitment required by a senior level job (the long hours watershed) and many knowingly and unwillingly limit their progression. Those women who do try to progress often do so at the cost of their own health and leisure time. These women engage in hugely complex daily routines using their greater earning power to find ways around the limited structure of opportunity by buying in services to support their domestic commitments (for example cleaners, childcare). Studies in the field of medicine have shown that even at training grades, some women select their area of medical specialism in anticipation of family life which they do not intend to embark on until many years in the future (Shaw 1980).

- Hakim's analysis of sex segregation has been subjected to a post structuralist critique (Position 3) which foregrounds the power of discourses and stereotypes in fashioning individuals' behaviour. Her suggestion that the perception of what is 'appropriate work' for women has changed – allowing their entry into occupations with a public face and no relation to domestic tasks has been taken up by scholars in the field of engineering, a sector in which at manual level there are a higher proportion of so called 'mixed occupations' but which remains male dominated at professional levels. Research into organisational dynamics argues that far from leaving domestic identities and hence roles behind, these continue to dominate women's experience in engineering occupations at both levels. For example work by Greene, Ackers and Black (2002) into the outcomes of restructuring practices in two manufacturing firms show that the association of certain types of work with women or with men were deeply embedded on the shop-floor and drew on notions of physical abilities such as 'women's nimble fingers'. Many women actively opposed a move to mixed team working missing an exclusively female space and the female sociability which could take place there; which represented an important strategy for coping with the monotony of factory work. Finally the tradition of family recruitment, stretching back to practices of patriarchal capitalism meant that the domestic was never absent in a workplace where parents and their adult children worked alongside each other. Bagilhole's study of women's strategies for fitting into the male dominated hierarchy of engineering academia also relied on ingrained notions of the sexual division of labour, women reported that they faced less resistance from men and achieved more if they were prepared to adopt familiar family roles, such as the office 'mother' (Bagilhole 2002).

- The prevalence of gendered stereotypes in young peoples' choice of topics of study are also part of this critique, since segregation in SET is partly linked to the low numbers of women at entry level.

Findings

The research evidence suggests that girls and boys engagement with science education begins to change and decline as they enter secondary school (Arnot 2000, Bentley and Drobinski 1995). This waning interest, for many pupils coincides with a lack of interest in school rather

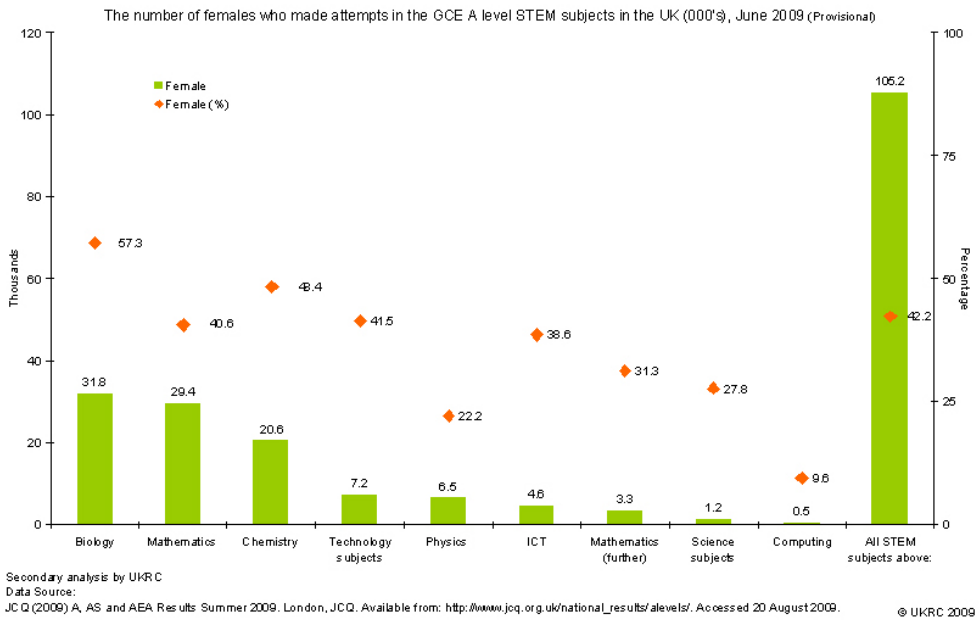
than arising from a rejection of science. At age 16 selection of science qualifications is mandatory in many schools for pupils of sufficient ability, however this is not the case at age 18. This results in low numbers of entrants for science subjects at 'A' Level. Although girls achieved higher grades in these qualifications than their male counterparts despite entering them in smaller numbers, these statistics indicate the beginning of the narrowing of the career 'pipeline'.

For example, the Gender, Employment and Local Labour Market Research Programme 2003-2006 (Buckner, Tang, Yeandle 2006) interrogated national datasets to demonstrate:

- Percentage of 17 year old population entered for mathematics 'A' Level in 2003 in England was 9.7% of boys 6.0% of girls. This compared with 7.9% of boys and 20.0% girls who entered for English.
- Of these pupils attending state maintained schools, a higher percentage of the girls entering mathematics 'A' Level achieved grades A-C (75.2%) compared with 69.2% of male entrants.
- The five most popular 'A' levels chosen by pupils in England in 2003, in order of popularity (excluding General Studies) were: Female: English, Psychology, Social Studies, Biology Sciences, Business Studies; Male: Mathematics, English, Business Studies, Physics, History

The UK Resource Centre's analysis of 'A' Level entrants for 2009 shows that girls are over 50% of entrants in Biology and have almost reached equivalence in Chemistry (48.4% of entrants). However in mathematics, technology and ICT girls remain around 40% with their numbers falling further in further mathematics and combined science. In physics they are just over 20% of entrants and computing only 10%. The 2009 results confirm the trend of girls performing well in the qualifications they attempt. Despite entering in far lower numbers girls performed better than boys in Physics by 2 percentage points and in computing by 2.6 percentage points (obtaining grades A-E).

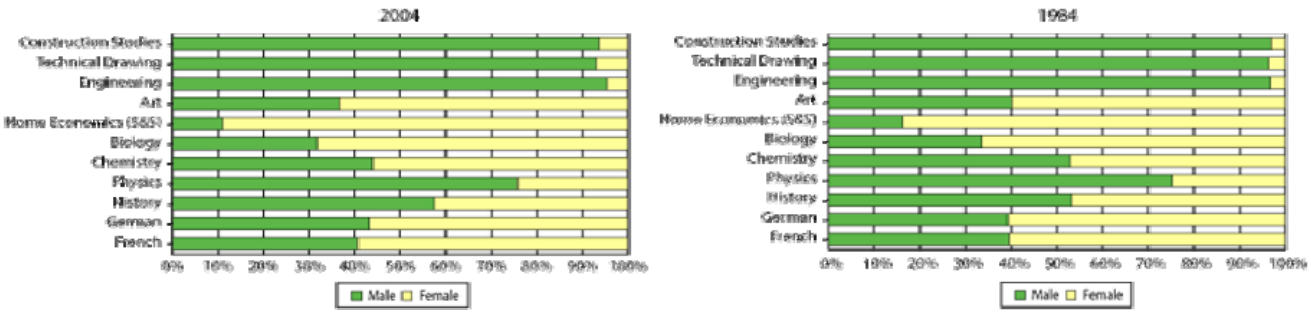
Figure 11: The number of females who made attempts in the GCSE A Level STEM subjects in the UK June 2009



http://www.ukrc4setwomen.org/html/research-and-statistics/statistics/primary-and-secondary-education-2009/

In Ireland, the change in the relative proportions of girls and boys achieving qualifications in SET subjects at age 18 has been relatively modest over the last 20 years, demonstrating the strength of gendered perceptions of SET subjects.

Figure 12: Leaving Certificate Candidates in Certain Subjects by Sex 1984/2004, Ireland



Leaving Certificate Candidates	2004		1984	
	Male	Female	Male	Female
Total Number of Candidates	**63,746**	**71,839**	**76,059**	**84,729**
Single sex comparison of subject choices	**%**	**%**	**%**	**%**
Physics	75.7%	47.5%	75.3%	24.7%
Chemistry	44.0%	24.3%	52.9%	47.1%
Biology	31.8%	56.0%	33.5%	66.5%
Engineering	95.3%	63.3%	96.7%	3.3%
Technical Drawing	93.0%	4.7%	96.3%	3.7%
Construction Studies	93.7%	7.0%	96.9%	3.1%

Source: State Examinations Commission
http://www.education.ie/admin/servlet/blobservlet/des_educ_trends_chapter06.htm#hd06_07

The gender differences between pupils pursuing a vocation qualification route leading to employment in SET trades are equally stark. There are only figures for England:

- Of 16-17 year olds who left full time education and entered employment in 2003, 43% of young men but only 4% of young women entered skilled trades.
- Apprenticeship starts in England 2006/07 illustrate very clearly the gendered choices and contexts in which young people are operating.

Figure 13: Number of Apprenticeship Starts by Gender in England 2006/2007

Apprenticeship Starts Selected Sectors	Women	Men	Women Ratio (%)
Hairdressing	12,548	1204	91.2
Health and Social Care	4,793	550	89.7
Customer Service	7,625	3,983	65.7
Engineering	140	5,592	2.4
Construction	212	16,323	1.3

Source: http://www.ukrc4setwomen.org/downloads/020_Female_Male_dominant_apprenticeships_2006_07.pdf

The percentages of girls obtaining undergraduate degrees and post graduate qualifications in STEM subjects 2006/2007 shows considerable consistency. As with young men the total number of female students continuing on to postgraduate level approximately halves.

Figure14: STEM first degree obtained at UK HE Institutions by sex, 2006/07

	Female	Male	Female %	Male %
Biological sciences (incl Botany and Psychology)	19,045	10,050	65.5	34.5
Physical sciences	5,475	7,005	43.9	56.1
Mathematical sciences	2,305	3,340	40.8	59.2
Computer sciences	3,090	13,355	18.8	81.2
Engineering and technology	3,085	16,815	15.5	84.5
Architecture, building and planning	2,245	5,370	29.5	70.5
All subjects above	35,245	55,935	38.7	61.3

Source: as for Figure 17

Figure 15: STEM postgraduate qualifications obtained at UK HE Institutions by sex, 2006/07

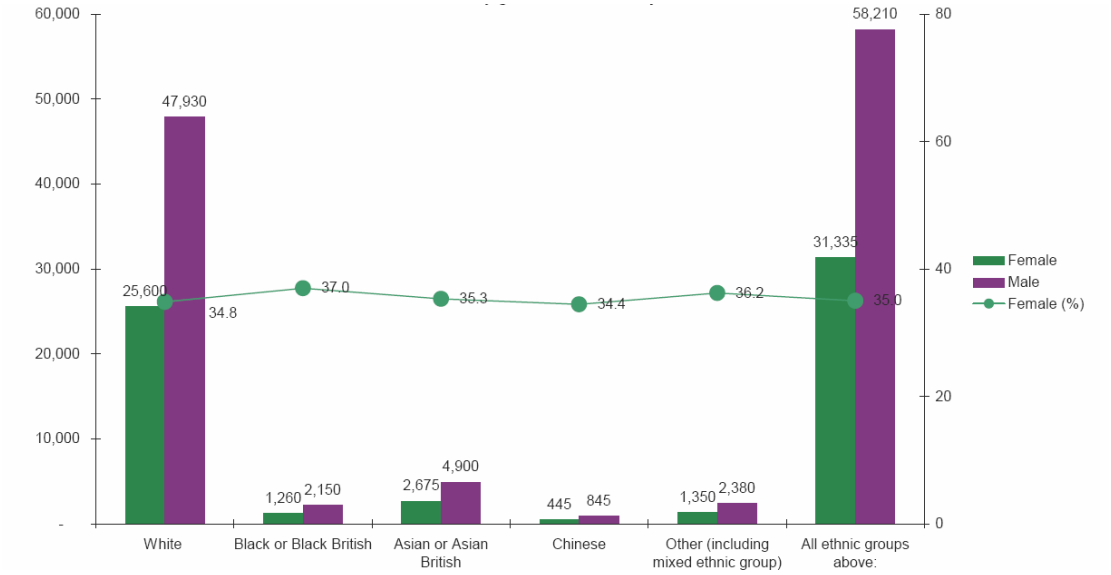
	Female	Male	Female %	Male %
Biological sciences (incl Botany and Psychology)	6,235	3,150	66.4	33.6
Physical sciences	2,785	3,610	43.5	56.5
Mathematical sciences	655	1,210	35.1	64.9
Computer sciences	1,825	6,605	21.6	78.4
Engineering and technology	2,645	10,625	19.9	80.1
Architecture, building and planning	2,345	3,410	40.7	59.3
All subjects above	16,490	28,610	36.6	63.4

Secondary analysis by UKRC
Data source: HESA (2008) Higher education student enrolments and qualifications obtained at higher education institutions in the United Kingdom for the academic year 2006/07. Cheltenham, HESA.
Available from: http://www.hesa.ac.uk/index.php/content/view/1100/161/. Accessed 6 November 2008 and
http://www.ukrc4setwomen.org/downloads/097_STEM_qualifications_obtained_2006_07.pdf

An analysis by ethnicity in the UK shows that by each ethnic group the proportion of women is also constant at around a third at undergraduate level. The proportion of women increases slightly at post graduate level to almost 40%.

Figure 16: Undergraduate qualifications in All STEM subjects obtained by UK domiciled students at the UK HE institutions by gender and ethnicity, 2006/07

	Female	Male	Female %	Male %
White	25,600	47,930	34.8	65.2
Black or Black British	1,260	2,150	37.0	63.0
Asian or Asian British	2,675	4,900	35.3	64.7
Chinese	445	845	34.4	65.6
Other (incl. mixed ethnic group)	1,350	2,380	36.2	63.8
All ethnic groups above	31,335	58,210	35.0	65.0



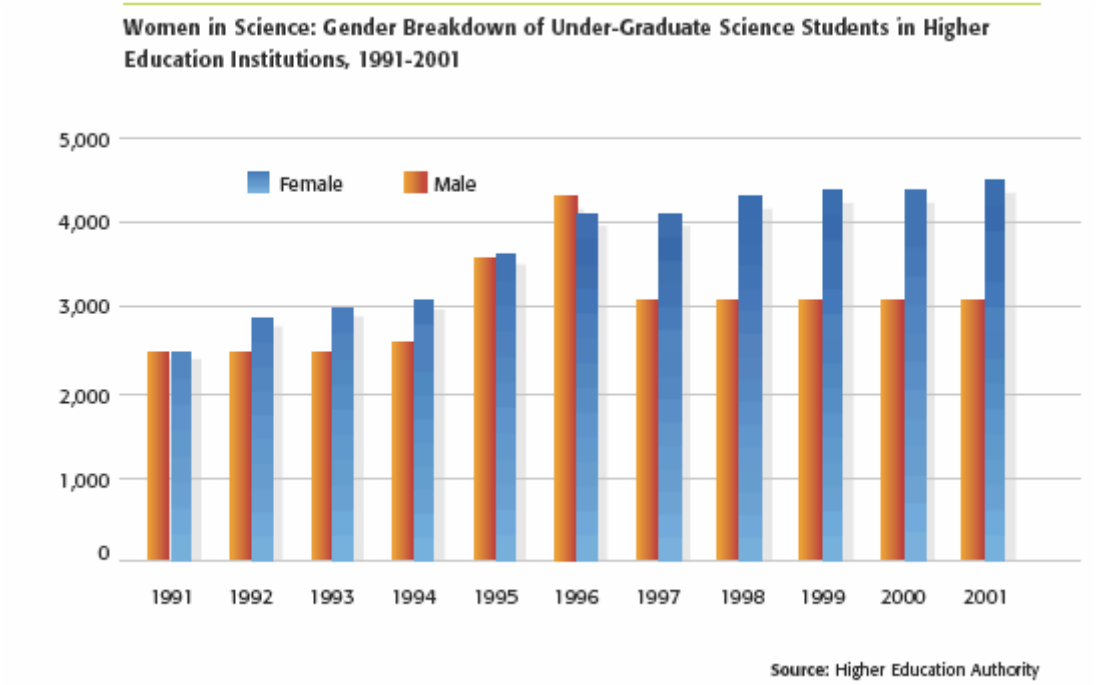
Secondary analysis by UKRC
Data source: Higher Education Statistics Agency 2009

Note:
1. This analysis excludes qualifications obtained by those who did not report their ethnic background, whose ethnicity was unknown, or who were non-UK domiciled
2. In this table 0, 1, 2 are rounded to 0. All other numbers are rounded up or down to the nearest multiple of 5. For this reason, some totals do not add up.
3. Calculations were made before rounding.

http://www.ukrc4setwomen.org/downloads/144_STEM_undergraduate_qualifications_by_gender_and_ethnicity_2006_07_Ver.2.pdf

Ireland compares favourably with other member states as female representation of women in sciences at degree and postgraduate level is higher than the EU average. Compared with the UK, a higher proportion of young people are entering higher education in the fields of mathematics, science and technology and numbers of Irish female PhD students are the highest among the European States, a phenomenon which may be linked to significant job growth in these areas since the 1980s.

Figure 17: Women in Science: Gender Breakdown of Under-graduate Science Students in Higher Education Institutions 1991-2001



Source*: Science and Technology in Ireland*, Prepared by Forfás in conjunction with the Office of Science and Technology, Department of Enterprise, Trade and Employment, 2004

Figure 18: Higher Education Graduates in the fields of mathematics, science and technology per 1000 of population aged 20-29, by sex 2003

	EU-25	IE	UK
TOTAL	12.3	24.2	21.0
Female	7.8	16.8	14.4
Male	16.8	31.5	27.6

Source: Eurostat Education statistics (UOE)
http://www.education.ie/admin/servlet/blobservlet/des_educ_trends_chapter10.htm#hd10_03

Figure 19: Proportion of Female Ph.D. Graduates in science, mathematics, computing, engineering, manufacturing & construction fields, 2003

	EU-25	IE	UK
TOTAL	37,026	381	7,491
Female	12,685	196	2,641
Male	24,341	185	4,850
%	34%	51%	35%

Source: Eurostat Education statistics (UOE)
http://www.education.ie/admin/servlet/blobservlet/des_educ_trends_chapter10.htm#hd10_03

However, an under-representation of women from the more male dominated subjects (linked to the traditional SET industrial sectors) of engineering, manufacturing and construction is still apparent.

Figure 20: HE Graduates in Ireland by broad field of study and sex, distributions and percentages, 2005

	Engineering, manufacturing & construction	Science, mathematics & computing	Other subject areas	
Distribution Women	3.3	12.5	84.2	100.0
Distribution Men	23.8	21.9	54.3	100.0
Women %	15.0	42.0		
Men %	85.1	58.0		
	100.0	100.0		

Source: Department of Education & Science
Note: Data on the distribution of graduates is based on 58,145 graduates in the above fields. Excluded are 332 graduates in Agriculture and 1173 graduates in the Services field.
http://www.education.ie/admin/servlet/blobservlet/des_educ_trends_chapter09.htm#hd09_01

Figure 21: First occupations obtained by UK domiciled STEM qualified graduates* by gender, 2005/06

STEM subjects studied for Qualifications / Occupations entered	Highest occupational group		Teaching Professional		Research Professional	
	Proportion of qualified graduates within subjects					
	Female %	Male %	Female %	Male %	Female %	Male %
Architecture, building and planning	35.3 Architect, town planner, surveyor	43.9 Architect, town planner, surveyor	1.1	0.9	1.1	2.0
Biological sciences	39.8 Other occupation	39.8 Other occupation	8.4	6.9	6.9	4.5
Computer Science	30.6 Other occupation	33.8 ICT professional	7.2	2.1	1.1	1.0
Engineering and technology	29.4 Engineering professional	42.2 Engineering professional	2.5	1.4	2.5	1.5
Mathematical sciences	27.4 Other occupation	26.1 Other occupation	13.7	6.8	2.7	2.8
Physical sciences	43.8 Other assoc. professional & technician	37.6 Other professional	1.0	1.3	2.5	4.6

* The analysis includes all UK domiciled graduates with first degrees, other undergraduate qualifications, and postgraduate degrees who found their employment.Secondary analysis by UKRC

Data source: HESA (2008) Destinations of Leavers from Higher Education Institutions 2005/06. Cheltenham, HESA.

In this table 0, 1, 2 are rounded to 0. All other numbers are rounded up or down to the nearest multiple of 5.
http://www.ukrc4setwomen.org/downloads/084_STEM_qualified_who_entered_SET_occupations_2005_06.pdf

Gaps

This section's findings have examined the quantitative evidence of horizontal segregation in science education and employment. Discussion of individuals' motivations and choices and the context in which these take place is taken up in proceeding topics.

Whilst a more consistent approach to the collection of national statistics is apparent in both the UK and Ireland, improving and continuing this development is crucial if trends are to be identified over time using comparable and credible data. The collection of data currently includes girls' and boys' selection of and achievement in different qualifications and training routes. This could usefully be linked to changes in the gender balance in individual occupations and industries over time and juxtaposed against national economic growth or decline.

There is a lack of research into certain dimensions of employment and related gender differences in the science sector:

- Comparisons of women's employment in academia versus industry (entry level, experiences, attrition rates) and the reasons underpinning women's choice of academic versus industrial career.

- Research to establish women's non traditional entry routes into SET disciplines, for example women starting in manual trades as entry routes into SET professional occupations.
- A closer examination of women's points of exit from science careers.

Whilst there has been prolonged and targeted funding in the UK to tackle the gendered selection and attainment of science qualifications and entry into science careers there is very little evaluation of what has worked and why. This analysis should include initiatives to assist pupils, students and workers.

5.2. Vertical segregation

Key Issues

Research into vertical segregation is concerned with the gendered appearance of occupational hierarchies. In the UK and Ireland senior positions are dominated by men, even in occupations where women are as numerous as men. Attention has been focused on women's professional careers, and the extent to which they have been able to advance to senior levels, focusing on the personal and structural barriers they have experienced. In science, particular issues have been the exit of women from the 'pipeline' career and the clustering of women into a few occupations ('feminisation' of certain jobs).

Analysis of the GSD provides the following description of the literature on which this section is based.

Number and percentage of publications

	n	%
Ireland	140	45.8
United Kingdom	469	45.0
Anglo-Saxon CS	**477**	**45.1**
All Cs	**2,035**	**44.7**

Relation with other topics

	%
Horizontal segregation	61.2
Vertical segregation	100.0
Pay and funding	30.8
Stereotypes and identity	46.3
Science as a labour activity	53.9
Scientific excellence	20.1
Gender in research contents	26.2
Policies towards gender equality in research	43.4

Average number of publications per year

	Average
1980-1984	2.2
1985-1989	2.4
1990-1994	5.8
1995-1999	14.2
2000-2004	35.0
2005-2007	47.3
2008-2009	18.5

Methodological approach

Empirical research	%
Non empirical research	41.5
Empirical research. Quantitative techniques	14.3
Empirical research. Qualitative techniques	30.2
Empirical research. Quali-quantitative techniques	14.0
Total	100.0
Approach	**%**
Conceptual	38.8
State-of-the-art	37.9
Compilation of statistics	24.9
Building gender indicators	3.4
Empirical research. Quantitative techniques	28.3
Empirical research. Qualitative techniques	44.2

Empirical research techniques

Quantitative techniques	%
Representative sample	48.9
Micro-data	34.1
Longitudinal/cohort	14.1
Multivariate analysis	42.2
Qualitative techniques	**%**
Biographical research	8.1
Case studies	23.7
Content analysis	7.6
Interviews	69.2
Observations	16.6

Research Questions

- To what extent are women under-represented in senior SET positions in the academe and industry?
- What barriers do women face when they try to advance their careers in SET?
- Can the metaphor of the 'leaky pipeline' explain women's under-representation at senior level? Are there better alternative models?
- What is the attrition rate of women from professional SET careers? At which points in the career path does this occur? Why do women leave?
- What initiatives have been undertaken to tackle vertical segregation, in SET academic and industrial organisations?

Research Approaches

The primary explanation of vertical segregation developed within the literature is the pipeline model (Berryman 1983) describing women's attrition from science. This model places motherhood at its centre and the responsibility with women for preferring to prioritise their children and families over career development. Whilst Preference Theory as it is currently conceptualised (Hakim 1991) may account for a minority of individuals' career exits, the contention that women are simply either 'work oriented' or 'adaptive' (prioritising home whilst wanting to fit in some paid work) is too simplistic to explain the decisions of the majority. It has been critiqued in a number of ways:

- for overlooking the ways in which women's 'choices' are shaped by their perception of the options available to them, which are in turn dictated by a multitude of inter-related factors such as: the cost, availability and reliability of childcare and adult social care (for dependent relatives) (Yeandle & Buckner, 2007); the impact of government polices e.g. tax and pensions; family background including their religion; the degree of family support for their career (Rose 1994); the availability of flexible working options and expected hours of work (paid and unpaid) (Fagan 2001); and a women's personal employment history which may be coloured by experiences of unemployment, job insecurity or difficult working environments (Grant et al 2006).
- for assuming that women's lives follow a linear course when in most cases women move between maximum and minimum work commitment according to their life stage and its associated commitments. (Crompton 1996, Crompton and Harris 1998, Fagan and Rubery 1996, Ginn et al 1996, Charles and James 2003).
- for suggesting that choices in favour of family imply an ambivalence on behalf of women about their careers, as this ignores the very great effort which women invest their employment, the work life balance solutions they devise and work hard to maintain, and the satisfaction and importance they attach to the product of their endeavours (Bennett et al, 2006).

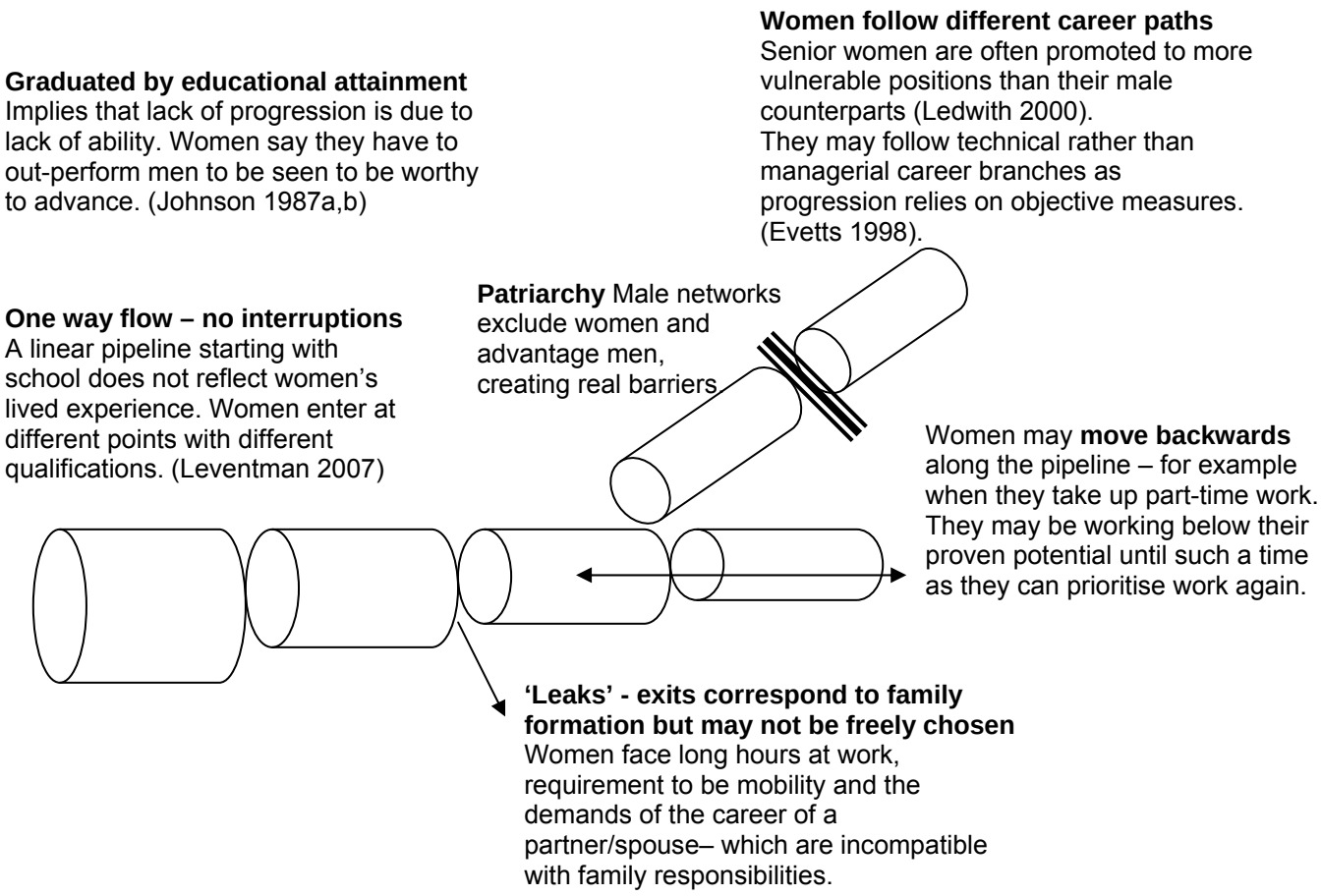
Women's choices *taken in context* are part of the explanation of vertical segregation, but so too are men's actions, now and in the past, through the operation of patriarchy. This is an area of research which is well developed in sociological literature but less so in the literature of the GSD concerned with science organisations. Men's greater access to education and the ethos of the male breadwinner half a century ago are still fashioning men an advantage in the senior ranks of science today. Other factors also come into play to uphold this privileged position, factors which make it hard for women with caring commitments to successfully compete for promotion. These include:

- Male networks, often enacted outside the workplace through participation in sport or other leisure activities. These networks operate to consolidate the ascendancy of its members through information sharing, grooming younger members, tolerance of a macho or sexist culture and rewards for perceived loyalty.
- Long hours culture. Fuelled by increasing pressure on science departments to increase outputs in times of economic economies, but also by the equation of commitment and hard-work with presenteeism in the workplace (Bennett et al 2006).
- Negative appraisal of part time working as a 'partial' engagement with work (Hochschild 1997).
- Requirement to move between institutions (and hence often cities) in order to move up the career ladder rapidly as the low turnover of staff means that individual departments can become stymied.
- Requirement to build up publication records, which demands the investment of significant amounts of out-of-work time.

It is likely that many men also struggle to overcome these factors, though the research to demonstrate the operation of dominant masculine cultures on the career trajectories of less advantaged men (Connell's concepts of hegemonic and subjugated masculinities, Connell 1987) in science has not yet been undertaken. In addition to these barriers, the nature of senior jobs also make them less attractive to some people as their function changes from undertaking scientific academic inquiry and experimentation to the management of others and the strategic direction of the organisation. Women and men voluntarily limit their progression in order to retain aspects of their jobs from which they derive most satisfaction.

Taking all these explanations together the pipeline model can be re-drawn to capture the deviations, obstacles and points of tension which women experience as they strive to develop a science career. The diagram below summarises the main critiques of the model which are aimed at improving rather than rejecting outright this way of conceptualising women's careers in SET.

Figure 22: Critiques of the pipeline model



This section goes on to review the quantitative research which describes the size and nature of the 'pipeline'. Evidence of the causes of vertical segregation is discussed in the following topics as it pertains to the influence of gendered stereotypes and perceptions, the structure and experience of the workplace and the policy context in which individual women make their choices.

Findings

Entry points into the scientific workplace and the subsequent trajectories of women's progression in SET careers decline even in subject areas where women undergraduates out-number men (for example in biological sciences where 60% of undergraduates are women).

As Figure 23 shows more women work in associate professional occupations than professional occupations. Overall the female workforce in science is very small; for example, just 8% of engineering professionals of working age are women compared with 48% in the UK workforce as a whole. Figures 24 and 25 underline women's absence from trade occupations and progressive exclusion from the financial and flexible hours opportunities offered by self-employment in these trades' occupations.

Figure 23: Science professionals/associate professionals by sex – numbers and percentages

Occupation Level		Female	Male	Total	Female %	Male %
Professionals	Science	26,700	45,700	72,400	36.9	62.1
	Engineering	39,200	426,000	465,200	8.4	91.6
	ICT	77,100	355,600	432,700	17.8	82.2
	Business & Statistical	89,300	177,000	266,300	33.5	66.5
Associate Professionals	Science & Engineering Technicians	96,300	299,300	395600	24.3	75.7
	IT Service Delivery Occupations	59,200	124,700	183,900	32.2	67.8
All occupations		16,731,200	18,190,700	34,921,900	47.9	52.1

Source: 2001 Census SARS, Crown Copyright 2004. This work is based on the SARs provided through the Centre for Census and Survey Research of the University of Manchester with the support of ESRC and JISC
Evidence from the 2001 Census prepared by Dr Lisa Buckner University of Leeds

Figure 24: Electrical, Construction, and Building Trades by gender and employment status in the UK, 2008

	Female	Male	Total	Female %	Male%
Electrical Trades	7,957	435,946	443,903	1.8	98.2
Construction Trades	7,695	918,558	926,253	0.8	99.2
Building Trades	-	250,628	253,304	n/a	98.9
All occupations above:	18,328	1,605,132	1,623,460	1.1	98.9
Other occupations	12,644,736	13,792,644	26,437,380	47.8	52.2

Secondary analysis by UKRC
Data Source: Office for National Statistics; Quarterly Labour Force Survey, January - December, 2008.
Distributed by the Economic and Social Data Service.
Crown Copyright material is reproduced with the permission of the Controller of HMSO and the Queen's Printer for Scotland.
Four quarterly datasets for 2008 were combined to create an annual dataset. Those respondents who did not report their occupations were not included in this analysis. .n this analysis, women aged 16 to 59 and men aged 16 to 64 were included. All figures below ONS guidance on publication threshold were replaced by '-'.

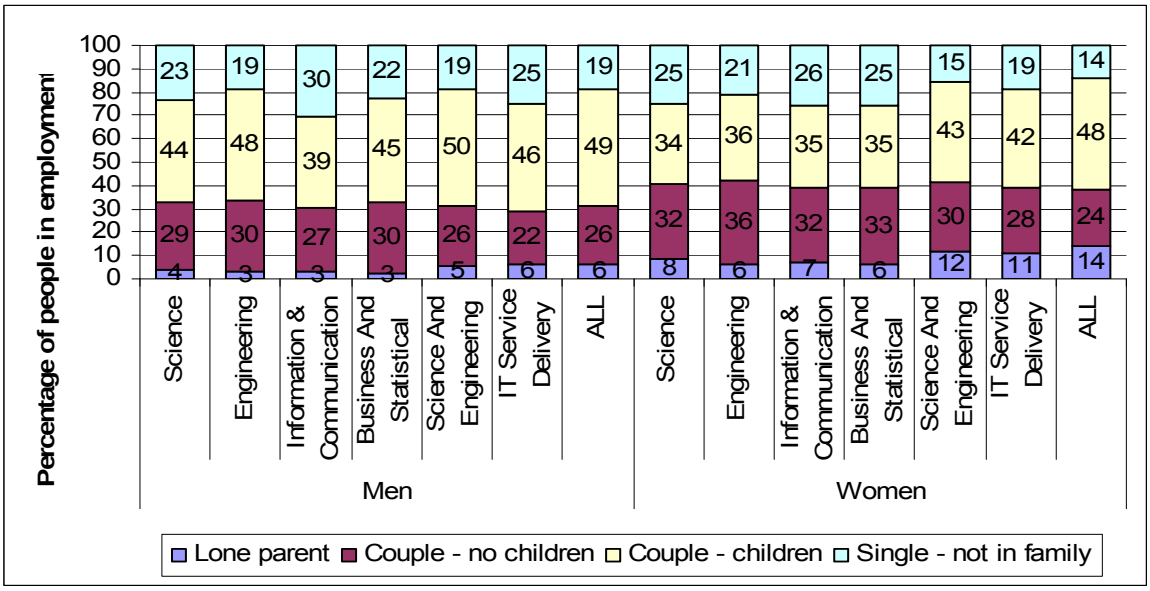
Figure 25: Self-employed SET workers[1] by gender in the UK 2002 and 2007

Year	Female	Male	Total	Female (%)	Male (%)
2007	29,901	278,590	308,491	9.7	90.3
2002	19,762	215,673	235,435	8.4	91.6

Secondary analysis by UKRC
Data Source: Office for National Statistics; Quarterly Labour Force Survey, January - December, 2002 - 2007.
Distributed by the Economic and Social Data Service.
Crown Copyright material is reproduced with the permission of the Controller of HMSO and the Queen's Printer for Scotland.
In this analysis, women aged 16 to 59 and men aged 16 to 64 were included.
Four quarterly datasets for 2002 and 2007 were combined to create an annual dataset.
This includes only those who reported they were employed at the time of their interviews. For a breakdown of SET occupations, refer to the SET occupation classification tab.

The decline of women's advancement is 'especially marked at the time in the life cycle where academic careers begin to take off and where qualified women start to have children'. (Osborn et al 2000 cited by Rees 2001). Figure 26 gives an insight into the demands which pursuing a scientific career places on an individual. There are significant proportions of both women and men remaining single without a family in these occupations compared with their counterparts in the workforce as a whole.

Figure 26: Science professionals/associate professionals by family type, sex, aged 16-SPA



Source: 2001 Census SARS, Crown Copyright 2004. This work is based on the SARs provided through the Centre for Census and Survey Research of the University of Manchester with the support of ESRC and JISC
Evidence from the 2001 Census prepared by Dr Lisa Buckner University of Leeds

Figure 27 breaks down occupational categories by age, revealing a two stage drop in the percentage of women working in science: first at the point of family formation (age 25-44) and second when the demands on women to provide care for older family members intensifies (age 45 to state retirement age). Figure 28, focusing exclusively on career progression in the higher education sector, shows the impact of women's exit on the gender breakdown at the most senior levels of academe. The data on women careers in Ireland's academy tells a similar story (Figure 29).

Figure 27 Science professionals/associate professionals by age and sex – percentage who are women

Occupation Level		16-24	25-44	45 – SPA*	ALL
Professionals	Science	43.2	41.6	28.1	36.9
	Engineering	13.6	11.1	3.7	8.4
	ICT	15.8	18.8	15.4	17.8
	Business & Statistical	42.2	40.2	18.1	33.5
Associate Professionals	Science & Engineering Technicians	25.2	25.8	21.9	24.3
	IT Service Delivery Occupations	24.0	32.5	39.9	32.2
ALL occupations		49.6	50.2	44.1	47.9

* SPA –State Pension Age
Source: 2001 Census SARS, Crown Copyright 2004. This work is based on the SARs provided through the Centre for Census and Survey Research of the University of Manchester with the support of ESRC and JISC
Evidence from the 2001 Census prepared by Dr Lisa Buckner University of Leeds

Figure 28: Career progression from GCSE to University Professorship in STEM subjects* in the UK, 2002/03 and 2006/07

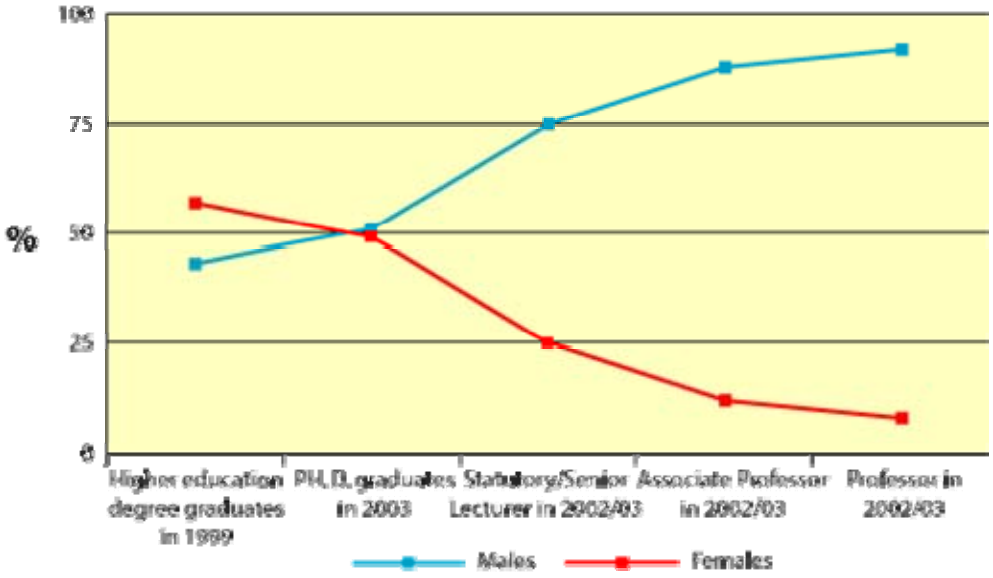
Year	Career Stage	Female	Male	Total	Female (%)	Male (%)
2002/03	GCSE Awards (England)	214,300	238,100	452,400	47.4	52.6
	A-level Awards (England)	67,975	85,225	153,200	44.4	55.6
	Undergraduates**	45,245	143,415	188,660	24.0	76.0
	Postgraduates**	10,055	29,745	39,800	25.3	74.7
	University Researchers**	4,295	10,035	14,330	30.0	70.0
	University Lecturers**	1,595	6,255	7,850	20.3	79.7
	University Senior lecturers and researchers**	730	5,235	5,965	12.2	87.8
	University Professor**	195	3,615	3,810	5.1	94.9
2006/07	GCSE Awards (England)	262,800	285,900	548,700	47.9	52.1
	A-level Awards (England)	73,315	91,226	164,541	44.6	55.4
	Undergraduates**	40,310	128,020	168,330	23.9	76.1
	Postgraduates**	10,130	31,810	41,940	24.2	75.8
	University Researchers**	3,990	9,835	13,825	28.9	71.1
	University Lecturers**	1,445	5,000	6,445	22.4	77.6
	University Senior lecturers and researchers**	1,005	5,485	6,490	15.5	84.5
	University Professor**	330	4,135	4,465	7.4	92.6

* In this analysis, STEM subjects include: Biology, Chemistry, Computing, Engineering, Mathematics, and Physics. Engineering is not included in GCSE or A-level awards.
** Only full-time students and staff.

Secondary analysis by UKRC
Data sources:
GCSE (2002/03) - DfES (2004) National Curriculum Assessments for Key Stage 3 and Key Stage 2 to Key Stage 3 Value Added Measures for Young People in England, 2002/03 (Final). London, DfES. Available from: http://www.dcsf.gov.uk/rsgateway/DB/SFR/s000473/SFR22-2004v3.pdf. Accessed 10 October 2008.

GCSE (2006/07)) - DCSF (2008) GCSE and Equivalent Examination Results in England 2006/07 (Revised). London, DCSF. Available from:http://www.dcsf.gov.uk/rsgateway/DB/SFR/s000768/sfr01-2008.pdf. Accessed 10 October 2008.
GCE A level (2002/03) - DfES (2006) GCE VCE A/AS Examination Results for Young People in England 2004/05 (Revised). London, DfES. Available from: http://www.dcsf.gov.uk/rsgateway/DB/SFR/s000630/index.shtml. Accessed 10 October 2008.
GCE A level (2006/07) - DCSF (2007) GCE/VCE A/AS and Equivalent Examination Results in England, 2006/07 (Revised). London, DCSF. Available from: http://www.dcsf.gov.uk/rsgateway/DB/SFR/s000769/SFR02-2008-corrected.pdf. Accessed 10 October 2008.
Undergraduate to Postgraduate (UK) - HESA (2004, 2008) Students in Higher Education Institutions 2002/03 and 2006/07, Cheltenham, HESA.
Researchers to Professors (UK) - HESA (2004, 2008) Resources of Higher Education Institutions 2002/03 and 2006/07, Cheltenham, HESA.

Figure 29: Ireland Graduation from Higher Education: Relative share of women & men in a typical academic career (all fields of study) (2000)



	Females	Males
	%	%
Higher education degree graduates in 1999	57	43
PH. D. graduates in 2003	49	51
Statutory/Senior Lecturer in 2002/03	25	75
Associate Professor in 2002/03	12	88
Professor in 2002/03	8	92

Data for academic staff relate only to HEA institutions
Source: http://www.education.ie/admin/servlet/blobservlet/des_educ_trends_chapter09.htm#hd09_01Source: Department of Education & Science and the HEA

Ireland has a higher representation of women in industrial scientific research (23.4% of R&D personnel) compared with the European average of only 13%.

Figure 30: Distribution of R&D Personnel, 2001

Distribution of R&D Personnel, 2001

	PhD Researchers	Non-PhD Researchers	Technical	Support Personnel	Total
Full Time Equivalents	597	5,374	1,748	1,407	9,126
% of Total R&D Personnel	6.5%	58.9%	19.2%	15.4%	100%
of which:					
% Male	82.9%	79.1%	76.5%	64.7%	76.6%
% Female	17.1%	20.9%	23.5%	35.3%	23.4%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

Source: Forfás

Source: :Survey of Research and Development in the Business Sector carried out by Forfás in 2001, reported in Science and Technology in Ireland, Prepared by Forfás in conjunction with the Office of Science and Technology, Department of Enterprise, Trade and Employment, 2004

Gaps

As political interest in the science workforce and equality has increased, so the requirement on institutions to collect data has become mandatory in the public sector. However, more work needs to be undertaken to secure the collection of longitudinal data and to synthesise data across institutions so that a comprehensive picture of women's and men's progress over time by science and organisation type can be presented. Very little data of the most basic details of gendered employment in the private sector has been collected, there is also almost no longitudinal data or analysis, this should be remedied.

It would be advantageous to know how the women (and men) who reach senior positions differ from those with flatter trajectories. This would require the collection of quantitative data identifying the biographical characteristics of professional senior SET women and men.

Studies in other contexts have shown that a significant percentage of women are working below their proven potential because of the lack of part time working at senior levels (Grant et al 2006). This issue has not been explored in science occupations. Quantitative research should be undertaken alongside qualitative studies of employers' assumptions underlying the construction of senior jobs.

Further application of Hakim's (1991) Preference Theory to women in science could produce important insights into women's career choices. Qualitative research needs to be undertaken to establish the lengths women go to, to maintain their commitment to paid employment, by balancing work and family life: do they readily exit when becoming mothers? There is some evidence that women have clustered into occupations and onto career paths which allow them greatest flexibility (this issue is explored in more detail in Section 5.5). The features of these 'feminised' enclaves could inform the design of jobs and environments in male dominated areas to make them more attractive.

A focus on men in SET is absent from the literature. Applying Connell's concept of hegemonic masculinity (Connell 1987) to science discilpines could reveal very contractory experinces of advancement and barriers, giving an insight into which men succeed and why, and ways of assisting those who have been frustrated in their efforts to advance.

5.3. Pay and funding

Key Issues

The most significant outcome of women's horizontal and vertical segregation is on their pay packets. The gender pay gap in the labour markets in UK and Ireland refers to the difference in average earnings between women and men, most often measured by an hourly or weekly rate. Before legislation upholding women's right to equal pay, direct discrimination played an important part in keeping women's wages low and their labour undervalued. Discrimination included employers' unilateral justification of lower wages and also women's exclusion from educational opportunities. Despite equality legislation prohibiting the differentiation of rewards on the basis of sex in the 1970s, women's wages have continued to trail behind those of men's. Explanations have shifted to structural factors drawing on an understanding of the sexual division of labour: occupational segregation, discrimination in pay systems and hierarchies and women's caring responsibilities.

Number and percentage of publications

	n	%
Ireland	46	15.0
United Kingdom	182	17.5
Anglo-Saxon CS	**184**	**17.4**
All Cs	**571**	**12.6**

Relation with other topics

	%
Horizontal segregation	52.7
Vertical segregation	79.9
Pay and funding	100.0
Stereotypes and identity	41.3
Science as a labour activity	56.5
Scientific excellence	26.1
Gender in research contents	26.1
Policies towards gender equality in research	47.3

Average number of publications per year

	Average
1980-1984	1.2
1985-1989	0.4
1990-1994	2.4
1995-1999	4.6
2000-2004	14.2
2005-2007	20.7
2008-2009	4.0

Methodological approach

Empirical research	%
Non empirical research	49.5
Empirical research. Quantitative techniques	19.6
Empirical research. Qualitative techniques	23.9
Empirical research. Quali-quantitative techniques	7.1
Total	100.0
Approach	**%**
Conceptual	44.6
State-of-the-art	40.8
Compilation of statistics	23.9
Building gender indicators	4.9
Empirical research. Quantitative techniques	26.6
Empirical research. Qualitative techniques	31.0

Empirical research techniques

Quantitative techniques	%
Representative sample	49.0
Micro-data	24.5
Longitudinal/cohort	8.2
Multivariate analysis	44.9
Qualitative techniques	**%**
Biographical research	3.5
Case studies	21.1
Content analysis	1.8
Interviews	71.9
Observations	14.0

Research Questions

- Is there a gender pay gap in academic careers in science? How does it vary by grade and occupation? Why does a gap to arise?
- What proportions of women and men apply for and secure research funding? How does this vary by subject?
- What barriers are there to women's successful attainment of research funding? Are these different from their male counterparts?

Research Approaches

The research interest in pay and funding in science followed the debate on women's progression raised by Berryman's 'pipeline model' in the early 1990s. Most of the literature dates from 2000 and falls into Position 2 since it is concerned with the inequalities produced by organisational practices and job structures. It focuses on employment in the higher education sector across all areas of study There is very little literature which focuses on the gender pay gap in science exclusively. Studies tend to describe the causes rather than attempt quantification, although individual science institutions have undertaken analysis to inform policy making and their negotiations with government, particularly in medical sciences, where recently the gender pay gap figures have been prominent (Perkins, A (2009) 'Plugging away at the gender pay gap' *The Guardian, 29 July 2009*). The processes of applying and awarding grant funding, which can be conceptualised as another type of resource accessed by academics, and crucial for career progression, has been examined across the University sector , though again, not specifically by Science Departments.

Findings - Pay Gap

The UK and Irish labour markets are highly segregated, 60% of women work in only ten occupational groups and women are clustered in the lower level, low skilled low-paid work. Organisational pay systems exacerbate the effect of this clustering. Individualised pay relies on the value judgements of gendered individuals and variance creeps in with bonus systems, over-time arrangements, and performance related pay. Women experience indirect discrimination because they start on lower salaries, are in occupations exempted from bonuses and overtime arrangements, take longer to qualify for long service awards and do not get judged the same as male counterparts in performance assessments. Caring responsibilities are often at the heart of women's inability to compete on equal terms with men. They continue to shoulder the majority of responsibilities for caring for dependent children and adults and this weakens their ability, and, for some, their willingness to engage in paid work that is full time or requires long hours. A 'partial' commitment to employment has traditionally been associated with a lack of ambition and orientation to the job in question and hence has come to be seen negatively by employers and associated with lower status jobs.

UK Pay Gap Facts and Figures

- The average hourly pay gap currently stands at 18% between men and women working full-time hours.
- The average difference in hourly pay between women working part-time and men working full-time is 41%.
- Women working full-time earn 72% of men's full-time average weekly earnings
- The 'mother gap' can equate to a loss in earnings of £140,000 over a lifetime.
- Female graduates earn on average 15% less than male graduates with the same qualification by the time they are 24.
- Training needed to gain skills and knowledge for higher-level positions is often offered outside of working hours, which can make it inaccessible to women with families.
- Men who join social networks are more likely to be promoted than women with family responsibilities who find it difficult to join networks outside of work hours.
- The pay gap is narrower where trade unions are involved in pay bargaining.

Source: http://www.iris.salford.ac.uk/GRIS/depict/GenderPayGap.html

Ireland's Pay Gap Facts and Figures

- The average hourly pay gap currently stands at 18% between men and women working full-time hours.
- The average hourly pay gap between women and men working part-time hours was 6%.
- In 1994, women's earnings were 81% of men's earnings in Ireland compared to 83% in the EU as a whole. By 2003 this portion had increased to 86% in Ireland compared to an EU average of 85%
- The difference in the labour market experience levels of men and women was the largest single influence in explaining the gender wage gap. Higher levels of educational attainment among women did help to reduce the wage gap. Other factors - such as a higher incidence of supervisory responsibility, longer tenure and higher trade union membership among men, and a higher incidence of part-time work among women - also widened the gap.
- In 1998, women comprised 40% of the bottom 10% of hourly wage earners, and 19% of the top 10% of hourly wage earners.
- While gross earnings in industry increased by almost a factor of two in the period 1984-2000, the gap between earning per hour of women and men decreased only very narrowly (0.1-0.2 of a percentage point).

Sources: http://www.meas.ie/page.php?intPageID=168#intSectionID331 and The Equality Authority and the Economic and Social Research Institute (ESRI) report *The Gender Wage Gap in Ireland: Evidence from the*

National Employment Survey 2003 by Seamus McGuinness, Elish Kelly, Tim Callan, Philip J. O'Connell. NDP gender equality unit publication *Women and Men in Ireland, Facts and Figures.*

In addition to attempts to tackle gendered occupational segregation covered in Section 5.3, a variety of initiatives have been proposed to close the pay gap within companies. These include job evaluation schemes to compare different jobs in order to define a basis for fairer grading on a single pay scale. Employers have been encouraged to undertake Equal Pay Audits to compare the pay of women and men undertaking work rated as equivalent to eliminate any gaps which are based purely on the grounds of sex. In the UK the Castle Awards were introduced in 1997 to recognise the efforts of employers to promote equal pay and opportunities in their workplace (Barbara Castle introduced the 1970 Equal Pay Act). In Ireland, social partnership arrangements have been prioritised since joint action through the implementation of the national wage agreement have helped to standardise wages both within and across firms and sectors, and this in turn has improved the relative position of women across all labour markets.

Explanations provided by the general sociological literature centre on organisational practices and fall into Position 2. McNabb and Wass (1997) have tracked the progression of full time academics over a thirty year period and conclude that a significant part of the pay differential between women and men is due to women's under-representation in senior ranks. However once factors such as this are controlled for there remains an unexplained 'gender effect'. There has been little change in the average gendered salary gap over the period. Chevalier (2007) has examined the 'unexplained' component of the gender wage gap and concludes that it can be explained by low female aspiration reflecting perceived discrimination or social pressure. Rees (2001) and Glover (2000) found evidence of an 'old boy network' directing the allocation of jobs and positions of influence, from which women are excluded. The power of these networks becomes apparent at particular points in the career ladder. Booth et al (2003) proposed the model of a 'sticky floor' where women find themselves just as likely to be promoted as men but in achieving a more senior position secure a lower starting salary than their male counterpart (Positions in UK Universities are assigned to different grades which consist of a series of incremental salary bands. Movement up the salary bands is automatic, subject to satisfactory performance, until the highest band in the grade is reached. At this point, an individual must formally apply and be assessed to be promoted to the next grade in order to increase their salary further. Research shows that women are more likely than men to be assigned to a lower salary band following promotion. They are then faced with having to 'catch-up'.) Other explanations for pay differentials appearing between male and female contemporaries blame women's lack of mobility due to family ties. Ward (2000) found that promotion to lecturer is a relatively high hurdle for women, initial placement and ability to move between institutions contributes to men's advantage in this rank / pay attainment.

The research on individual science disciplines is scant. Evetts researching Engineering found the female SET employees tend to be concentrated in lower status positions than their male counterparts (Evetts 1993a, 1998). They receive lower pay and benefit packages (EOC 2004, Roberts and Ayre 2002, Martin 2001).

The IRIS project hosted by Salford University focused on ICT professionals. Its findings accord with broader pay gap literature:

- Individualized pay packages are common in the IT industry, which involves strong negotiation skills and a high level of confidence; these are traits that many women do not naturally possess.
- There is a culture of 'salary secrets' in the IT industry and women have reported that they only find out about pay inequalities once they reach management level and have access to the information.
- Employers expect confidentiality about pay and disclosing this information to colleagues can lead to disciplinary action.
- The Women in North West IT (WINWIT) project (2004) reported gaps in annual salaries of as much as £17,000. Women were also reported to have experienced discrimination in pay and promotion after returning from maternity leave and choosing to work family friendly hours (Adam et al, 2004).

- Many women with caring responsibilities choose to work part-time; this is often incompatible with working in the IT industry as part-time working is rarely an option.

Figure 31: Median hourly pay excluding overtime (£) of selected full-time SET professionals by gender in the UK, 2008

SET Professionals / Sex		2002	2003	2004	2005	2006	2007	2008
Science Professionals	**F**	12.6	13.2	14.1	14.9	15.2	15.9	15.9
	M	14.8	15.1	15.6	16.5	17.1	17.4	18.0
Engineering Professionals	**F**	12.8	12.7	13.6	13.7	15.1	14.6	15.5
	M	14.6	14.9	15.4	15.9	16.3	16.6	17.4
Architects, Town Planners, Surveyors	**F**	12.5	14.2	14.8	14.6	15.1	16.7	17.2
	M	14.6	15.4	15.8	16.8	17.3	17.6	17.9
Science and Engineering Technicians	**F**	8.8	9.2	9.6	10.2	10.1	10.1	10.2
	M	10.7	10.8	11.1	11.4	11.7	12.3	12.9

Secondary analysis by UKRC
Data source:
Annual Survey of Hours and Earnings (ASHE) - 2002 to 2008 Results.
Available from: http://www.statistics.gov.uk/. Accessed 2 October 2009.

Findings - Funding Allocation

While fewer female academics (50%) apply for research funding in SET compared with men (59%), the proportions of successful male and female applicants are similar (Blake 2000). Blake's study established that there were no gender differences in applications for competitive fellowships. However eligibility was an issue in Research Council and Wellcome Trust funding which set criteria preventing those on fixed term employment contracts from applying. This criteria affects proportionally more women than men. Millard's and Ackers' contribution to '*The Gender Challenge in Research Funding: assessing the European national scenes'* (European Commission 2008:130) examined in detail the gender breakdown of applicants and award-holders of standard research grants issued by the UK Research Councils. As would be expected the percentages of women applicants were highest in areas of science where they were most numerous. For example, figures for 2007/2008 showed that women made up 22% of applicants to the Biotechnology and Biological Science Research Council (BBSRC) compared with only 13% to the Science and Technology Facilities Council (STFC). Their findings supported Blake's (2000) observation that female applicants attain a proportionally higher success rate.

Some of the explanations why women fail to secure equal pay equally relate to their participation in grant funding applications since a successful track record of grant funding awards can be used as a criteria for promotion. Fletcher et al (2007) found that women are prevented from a full and equal involvement in research within academic departments by a lack of transparency, increased competition and reduced collegiate activity coupled with networking based on homosocioability.

Gaps

The research on the gender pay gap and funding allocation in science occupations has not yet presented a complete picture of the size and degree of inequality by science discipline.

Also missing is data about:

- the relationship between the gender pay gap and the degree of vertical segregation in SET;
- a comparison of the gender pay gap in trade versus professional (academic and industrial) SET occupations;
- the pay penalties which SET women incur because of career breaks (for example to care for children or dependents);
- the impact of part-time working on the gender pay gap in SET;
- the role of SET unions (the social partners) in negotiating pay settlements and their influence on gender pay equality.

5.4. Stereotypes and identity

Key Issues

The embeddedness of sex-role stereotypes and identities has been one of the most significant explanations for the continuing segregation of women and men into different industries and occupations within the labour market. The focus of research has shifted over time, following the broader trends sociological theory, described in Section 2. This chapter aims to identify these shifts whilst acknowledging that the categorisation of individual research studies into theoretical positions can be indicative at best.

Primarily the investigation of sex-role stereotypes and identity in the Anglo Saxon literature has been used to explain horizontal segregation in terms of gender distinctions in education: pupils' choice of subjects to study at school and university and their experiences in the science classroom. Explanations of vertical segregation have included an examination of the development of and consequences for women of stereotypes in the workplace as well as their ways of coping with them through the adoption of particular identities. Research in this area overlaps Section 5.5 Science as a Labour Activity.

Although our focus is on gender, women and their under representation in science disciplines is the key issue explored in the publications of the GSD relating to stereotypes and identity. In the 1990s a concern about boys' under-achievement at school level assessments and qualifications emerged following clear evidence of a lag in national education statistics. However this area of literature has remained secondary in the discussion of gender and stereotypes and focuses on boys overall performance rather than highlighting their failing engagement with science education.

Analysis of the GSD provides the following description of the literature on which this section is based.

Number and percentage of publications

	n	%
Ireland	129	42.2
United Kingdom	604	58.0
Anglo-Saxon CS	**607**	**57.4**
All Cs	**2,458**	**54.0**

Relation with other topics

	%
Horizontal segregation	61.4
Vertical segregation	36.4
Pay and funding	12.5
Stereotypes and identity	100.0
Science as a labour activity	29.2
Scientific excellence	14.3
Gender in research contents	32.9
Policies towards gender equality in research	32.9

Average number of publications per year

	Average
1980-1984	3.6
1985-1989	7.0
1990-1994	11.4
1995-1999	22.2
2000-2004	38.0
2005-2007	54.7
2008-2009	16.0

Methodological approach

Empirical research	**%**
Non empirical research	40.5
Empirical research. Quantitative techniques	19.3
Empirical research. Qualitative techniques	28.8
Empirical research. Quali-quantitative techniques	11.4
Total	100.0
Approach	**%**
Conceptual	39.4
State-of-the-art	36.7
Compilation of statistics	13.5
Building gender indicators	1.8
Empirical research. Quantitative techniques	30.6
Empirical research. Qualitative techniques	40.2

Empirical research techniques

Quantitative techniques	**%**
Representative sample	45.2
Micro-data	33.9
Longitudinal/cohort	9.1
Multivariate analysis	52.2
Qualitative techniques	**%**
Biographical research	8.6
Case studies	21.7
Content analysis	3.3
Interviews	63.9
Observations	27.9

Research Areas

- Defining gendered stereotypes and the extent of their influence over cognitive ability, personal preferences and perceptions as they relate to SET education and employment.
- Structures and contexts which contribute the gendered socialisation of young people and their subsequent adoption of stereotypical roles.
- Use of gender stereotypes in the workplace, for what purposes and to what ends

Research Questions

- How are young people's choices of subjects shaped by gender socialisation in the home and teaching contexts?
- Are there essential gendered characteristics / personality traits which predispose girls and boys to SET subjects?
- Do girls and boys adopt different identities when studying science? How do they differ?
- What are the 'at work identities' of professional senior SET women? How do they differ from other women, from men? Who imposes them?

Research Approaches

The under-representation of women in science education has been theorized in terms of the normalisation of sex-role stereotypes which are so pervasive and engrained that they have gone un-challenged, consequently gaining re-enforcement decade on decade as the number of women entering science continues to be relatively small. The adoption and internalisation of sex appropriate stereotypes can be described as part of the process of 'gendered socialisation'. These stereotypes are described as 'binary-dualisms' as they juxtapose male and female traits, describing a stronger association of men and male attributes with the pursuit of scientific activities and scientific invention. These dualisms are present in popular perceptions, images and discourses. They reference actual practices and structures of opportunity which have emerged in the classroom, labour market and at home and have historical starting points. These include:

- girls' later entry to higher education
- men's dominance in skilled scientific / manufacturing occupations through processes of unionisation (Cockburn 1985a)
- women's exclusion from the labour market following marriage
- the construction of 'part-time' jobs to secure women's paid labour alongside their unpaid labour in the home
- and the sexual division of labour which expects women to shoulder a greater share of caring and domestic labour.

Individuals' perceptions and internalisation of stereotypes, influenced by what they see and hear around them can be shown to influence their choice of educational studies. However, it is not possible to isolate their influence from the context of everyday lives, to demonstrate unambiguously a generalisable cause and effect. Despite this, research over the last three decades has not remained static; academics have refined our understandings of the dualisms and looked more deeply into parental, scholastic and workplace attitudes to discover the sophisticated and subtle ways which dualisms pervade our thinking. This endeavour has led to research which has deconstructed teaching styles and content, de-coded media images and the design of physical technology as well as critiqued the agendas of scientific research itself. Dualisms have also been shown to colour managers' expectations at work and measurements and definitions of success. A more recent development has been the exploration of the ways dualisms create particular types of scientific identities from which women and men must choose if they want to 'belong' to a particular science occupation or even 'fit into' a local team. The performance of gendered identity through repeated construction, re-construction and reinforcement is an area of theory which has been applied to some science workplaces with important explanatory results.

Arguably the most potent of the sex-role stereotypes is the primary one articulated by scholars in the first wave feminist movement; the association of masculinity with objectivity and rationality and femininity with subjectivity and emotion. This dualism has obvious resonance in the scientific arena, going hand in hand with the equally longstanding assumption that the pursuit of scientific knowledge can be objective and aim to uncover essential truths. Some theorists have gone as far as to claim that rather than men being better suited than women to scientific study

because of their aptitude for rational thought that a scientific viewpoint on the world is the defining characteristic of masculinity (Mendick 2003).

From the GSD it is possible to observe that research about gendered horizontal segregation was guided by this dualism of rationality versus emotionality in the 1980s (Position 1), focusing on the question – Why do girls not choose to study science subjects at school or university? One branch of this literature has attempted to establish that sex-role differences are rooted in biological differences. However there is weak and inconclusive evidence to support the explanation that boys greater proclivity and aptitude and selection of science is due to essential cognitive, physical or hormonal sex differences. The majority of publications falling into this position explore the socio-cultural reasons. For both girls and boys there is a focus on what attracts them to science and the ways in which science curricular content relates to their personal (gendered) interests. Studies conducted in the 1970s and 1980s established gendered differences in the selection and achievement of mathematics and science examinations at school; that more girls than boys were opting out of, or performing poorly in these subjects (Sharpe 1976, Spender 1982 and Stanworth 1981). Explanations for this centred on patriarchal learning environments and gendered teaching styles and stereotyping. The introduction through the Education Act 1988 of a National Curriculum, wherein all pupils have been required to follow the same programme of study up to the age of 16 (incorporating mandatory maths and science examinations) reversed this situation for GCSE examinations results (Younger and Warrington 1996, MacInnes 1998). However, at post-compulsory education the gendered differences return and remain marked.

There is no hard and fast line to be drawn between the 1980s studies and those which were developed in 1990s except to note that researchers addressed the growing policy concern that the numbers of scientists were falling and that boys in school were underachieving relative to girls (Epstein et al 1998, Griffin 1998 and Yates 1997). The focus of research in this decade (Position 2) widens from looking at individual motivations and decisions to the contextual influences acting on pupils and students. No longer tending to look for straightforward, unproblematic relationships between stereotypes and individual choices, but rather recognising a messy web of different factors at work. In parallel with trends in sociology to theorise structural disadvantage and discriminatory practices, research has looked at the public and private spheres to find the ways in which stereotypes affect teaching practices and parental and career guidance and the image of science in the media. In Position 2 literature and in the decade of literature which has followed it the conceptualisation of the nature of binary dualisms has become more sophisticated. Attention to structural influences has gone alongside the recognition that men have come to be associated with discovery and creation played out through active public life, relegating women to a sex-role preoccupied with nurturing in the domestic sphere. Contributions from organisational theorists have demonstrated the ways in which this dualism is embedded within organisational cultures and supports women's choice of particular sex-roles. It also underpinned research into women's relationship with and contribution to the development of technology and the built environment. This is portrayed as one of passive user not creator, leading to their alienation from technology and the physical environment and their needs being overlooked in the design process.

Early this century challenges to social constructivism by post-structuralists have moved the analysis of gendered stereotypes from an interest in people's behaviours and life choices, to the differences in their perceptions of the world and the power of discourses to shape their thinking. Research has shifted once again in a number of different directions: earlier work on sex-role based choices has been problematised in the light of competing discourses; there has been a renewed investigation of 'pleasure' in science developing from the exploration of 'gendered interests'. New areas of investigation include women's muted contribution to the design of the physical world and the implication of this omission, similarly the exclusive nature of the processes of generating scientific knowledge has also called into question its validity and usefulness in speaking to women and men and the diversity between women and between men (taken up in greater detail in Section 5.7 Gender in Research Contents).

Findings

Driven by concerns about skills shortages linked to a negative impact on economic growth, the publications produced in the 1980s and early 1990s were trying to establish why girls were not choosing to enter the SET industries (Position 1). The binary dualism of masculinity associated with the objective pursuit of technology and femininity with an emotional connection to the social is evident in many investigations of the ways socialisation of skills in the family from a young age influence girls' and boys' understanding of desirable 'gender characteristics' which in turn shapes their future interests, educational choices and their adult role expectations (Lynn 1966, Schwartz 1996).

The starting point of much of this research is the observation that *the interest value* of the subject is a major factor in girls' and boys' science subject choices. (Garratt 1986). There have a been a number of studies which have questioned young people about their choice of subjects at 14 and discovered that whilst boys' and girls' perceptions and approaches to science are similar, a significant difference lies in the match between their leisure pursuits and some aspects of practical science. This is particularly true of computing science where more boys admit to spending more time playing computer games than girls (Durndell 1997, Cantwell Wilson 2002). Johnson's work suggests why this confers an advantage, she argues that traditional boy's leisure activities equip them with relevant skills which are useful in scientific practical work and give them an experiential base on which to build an understanding of mathematical concepts. Solomon (1997) highlights the 'comfort value' which boys develop with technical concepts because of their greater exposure to them. Engagement with the subject matter also gives boys a means of affirming their identity with peers since it is a leisure pursuit which they often share with others. Murphy and Whitelegg found that girls tended to be more fearful about the difficulty of the science subjects which the authors explained was due to the underlying dualism (Murphy and Whitelegg 2006). Walkerdine suggests that this is further reinforced by the tendency of teachers to associate girls' achievements with hard work rather than 'natural' ability (Walkerdine 1990).

Bell's (2001) work on young people's choice of biology and physics came to the same conclusion about interests revealing more about girl's preferences for *subjects with a social dimension*. Lightbody et al (1997) have argued that young women are more attracted to courses which lead to careers with higher levels of social involvement rather than repelled by courses with technological aspects, medicine being one such example, biology another. Taber found that on starting secondary schools girls already showed a strong preference for biology and boys for topics with a mechanical connection (Taber 1991). Woodward's and Woodward's examination of the effects of the primary curriculum also found that girls were more interested in biology, they concluded that girls subject interests cannot be successfully broadened by curricular changes alone (Woodward and Woodward 1998). Teachers' reception of this message appears to be mixed; Hughes found that socio-science as a part of curriculum development has been devalued through comparison with the higher status of abstract 'masculine' science: Teachers fear that its inclusion not only devalues the overall content of the curriculum alienating traditional science students, but also jeopardises their own status as gatekeepers of scientific knowledge (Hughes 2000). Others disagree, Beraud found support for interdisciplinary routes which incorporate socio-economic content to attract women to engineering degrees (Beraud 2003).

Murphy, P. & Whitelegg, E. (2006), 'Girls and physics: continuing barriers to 'belonging'', *Curriculum Journal*, vol. 17, no. 3, pp. 281-305

Murphy and Whitelegg have conducted an extensive literature review of national and international research about girls' participation in physics (177 sources).

They conclude that:

- Prior achievement and perceptions of the difficulty of physics are important factors in all students' decisions about whether to continue to study the subject at a higher level.
- The content and methods of approaching physics problems and investigations more closely reflect what boys engage with outside school: these activities are associated with what culture defines as 'masculine' rather than 'feminine' attributes.
- These gendered stereotypes of 'who does physics', influence girls' engagement with the subject, their sense of self-efficacy in relation to it, and their perception of its personal relevance. More girl than boys fail to see their future self engaged in physics and physics-related careers.
- These perceptions can be disrupted by changes in the curriculum and in single-sex pedagogical experiences which can foster a greater sense of 'belonging' for some girls.

Age and its importance in attitude formation is implicit in many studies but very few have looked at the way that young people' experience of the world as they mature alters their perceptions of gendered stereotypes in science. Francis found little understanding of the nature of the adult labour market among a 14-16 cohort of girls and boys, whose gendered aspirations were out of kilter with the realty of contemporary jobs (Francis 2002). Similarly Solomon noted that older women's choices were not shaped by a need to affirm their feminine identity with their home culture or that of their female peers and arose from different motivations (Solomon 1997). Evidence collected in schools in 1990s has shown clearly that negative attitudes towards science education forms at a particular point in secondary school studies. During the first three years girls' and boys' attitudes towards maths and science subjects have hardened with girls showing a more pronounced decline (Barmby, Kind and Jones 2008). This is supported by the results of a large attitudinal study of young people aged 13-14 conducted in Wales to compare attitudes towards English and sciences (Hendley et al 1995).

Questions about *essential gendered behavioural and personality differences* linked to early socialisation have been asked of pupils at school. For example, behaviours exhibited in working relationships in the classroom suggested to Tolmie and Howe (1993) that boys are more likely to probe and test each other's individual ideas whereas girls will avoid conflict by looking for common ground. Since both empiricalism and generalisation are central to scientific methods the authors argue that both behaviours should be encouraged. Similarly Billington et al's (2007) assessment of cognitive styles found that choice of physical science subjects was linked to girls and boys with stronger synthesising drives than empathizing drives and that sex became significant because more boys had this drive than girls. Hacker put it another way, that young men exhibit 'strong barriers to communicating emotion' and a predisposed fascination in how things work (Hacker 1981). Not all research upholds the inevitability of gendered socialisation.

Research undertaken in the late 1990s exhibits a more situated understanding of the binary dualisms under pinning stereotypes and hence perceptions; moving on from the straightforward association of men with technology and rationality to their association with discovery and public life and women with the home, nurturing and domesticity. There have been a growing number of researchers in the field of education arguing that 'girl friendly' science teaching can overcome restrictive perceptions of normalised roles. Gender-aware teaching and single sex teaching have both been identified as approaches that are effective in changing pupils' attitudes (Shuttleworth & Daly, 1997). Blekinsop et al (2006) showed that schools which provided mechanisms for supporting pupils aged 14-16 in their decision-making, such as individual talks

with teachers and career advisors, were able to increase their influence making pupils less reliant on family and friends, with implications for pupils' choice of science subjects. (also Roger and Duffield 2000). Women scientists in Devine's study confirmed that specialist teachers in their single sex-schools had been an important source of support in the face of considerable opposition to their choice of non traditional careers from non specialist teachers and unenlightened careers teachers. (Devine 1993). Sullivan's (2008) measurement of 'academic self concept' showed that girls scored higher in maths and science when taught in single sex groupings.

Other academics have argued that in some disciplines the influence of stereotypes and gendered identities have been over stated. Head and Ramsden (1990) used a popular personality inventory[2] to identify a common psychological type in girls who chose to study physics (a majority of girls choosing science in their study were in the 'Sensing Judging' quadrant; meaning that they were realistic decision-makers who focused on the facts of immediate experience, seeking an ordered environment). They found it was possible to interest other personality types through appropriate interventions in school teaching, demonstrating that that personality and choice were not necessarily immutable. Bentley and Drobinski (1995) found that tailored teaching using a problem solving approach (CREST Creativity in Science and Technology) changed girl's attitudes positively towards science. Research in the fields of accountancy and maths at under-graduate level demonstrated that students' approaches to learning, and the ability of the institution to match them, made more difference to their academic performance than either their gendered identity or sex (Paver and Gammie 2005, Kelly 1999).

In contrast to the consensus in the literature that teaching makes a difference, there is a lack of consensus in the research about the strength and importance of parental influence. For example, Kelly et al's study of parents of children in their first year at secondary school found that the majority held egalitarian attitudes towards girls' choice of science subjects and careers with little variation by socio-economic class. However these attitudes coexisted with traditional assumptions about male breadwinners, and women's caring roles. Also parents' own division of domestic labour and their expectation of their children's contribution to home life was strongly sex-stereotyped. Kelly concluded that children receive contradictory gender messages, which are not as uniformly traditional as interested observers assume. (Kelly et at 1982)

Other studies place their onus on the importance of *gendered imagery of scientists* affecting young women's choices in surreptitious and subtle ways. Phipps' (2002) examination of 'cultural' stereotyping, puts forward a strong case for positive images of female engineers to redress the balance in the context of gender blind industry public relations. Inadvertent stereotyping can be present in a multitude of environments; Machin's study of a natural history museum found an andocentric bias in both the physical displays and supporting text reflecting both historical and current views of gender within the museum and beyond (Machin 2007). Mendick's work on films demonstrates a strong association of masculinity with heroic representations of mathematicians which she argues are ubiquitous in popular film and television (Mendick et al 2008).

Interest in the identification of subliminal gendered stereotypes, familiarised in everyday discourses and images has grown alongside the preoccupation in sociological research with post structural analysis in 2000s. One such study by Corneliussen (2005) adeptly illustrates the way in which a hegemonic discourse associating working with computers with male pleasure positions women in the field as 'the other' to such a extent that they report great surprise at 'discovering' their own enjoyment of programming. They have then enjoyed the exclusive status conferred on this male pursuit and borrowed the discourse knowingly to impress others. Mendick (2005) and Wilson and (2003) have demonstrated men's unquestioned acceptance of and benefits from these types of discourses.

[2] Myers-Briggs Types indicator is a personality inventory based on the theory of psychological types described by C. G. Jung. It describes four bipolar parameters; Extraversion – Introversion, Judging – Perceiving, Sensing – Intuition, Thinking – Feeling.

Contemporary research has begun to get to grips with much more complex processes of 'identity work' undertaken by young women and men, who form and project their identity against a back drop of many gendered discourses. For example, among pupils questioned about 'being good at maths' Mendick discovered that their replies were mediated by a series of binary opposites such as competitive/collaborative, active/passive, naturally able/ hardworking as well as reason/emotion. (Mendick 2005). Stepulevage observed evidence of girls 'constructed incompetence' in secondary school computing and technology classrooms in order to fit with gendered expectations of their peer group (Stepulevage 2001). Similarly in their study of medical students, Clack's and Head's empirical investigation of perceived attributes found that these were split between women and men along gendered lines: men felt better equipped with 'a spirit of curiosity' and 'leadership potential' compared with women who felt more confident in their 'ability to listen', 'work in a team' and to 'inspire confidence in others'. (Clack and Head 1999).

In contradiction to this literature arguing for masculine advantage, there is a growing body of literature about boys' underachievement and disenfranchisement from education because of expectations of how 'to do masculinity' which disrupt their engagement in learning (Burns and Bracey 2001). Davis has observed that boys' learning strategies and ways of communicating are not conducive with high achievement; the process of pupils' learning through talk-related activities reveals that while girls' talk is conducive for cooperative learning, boys' constructed definitions of heterosexual masculinity are in conflict with the learning environment in a manner likely to impact on their examination results (Davies 2003). Skelton is one of several voices arguing that as well as gender, discourses associated with ethnicity and socio-economic group is also significant in determining performance for boys as well as for girls. (Skelton et al 2007).

Most research on 'identity work' has been undertaken by organisational theorists interested in women's underrepresentation in scientific hierarchies rather than in women's education. Following Kanter's (1977) ground breaking contribution detailing women's gendered performances' at work and their limitation to one of four stereotypes, all reminiscent of women's positions in the domestic sphere, Evetts 1998 found that women in engineering followed one of three distinct strategies: 'fronting it out' (confronting sexism) 'playing the little women' (tolerating sexism, employing gendered techniques such as crying) 'displaying technical competence' (building an unquestioned reputation). Savage and Witz observed that women working in SET have to deal with a constant tension of trying to be a women yet not behaving like one. (Savage and Witz 1992, also Greed 1991 and Adam et al 2006). Female academics may even internalise or collude with a stereotype of women's intellectual inferiority; refusing to consider promotion due to lack of confidence, or maintaining a low opinion of their performance to uphold the status quo and not to appear threatening to male colleagues (Bagilhole 2002)

Hughes, G. 2001, 'Exploring the Availability of Student Scientist Identities within Curriculum Discourse: an anti-essentialist approach to gender-inclusive science', *Gender and Education*, vol. 13, no. 3, pp. 275-290.

Hughes has deconstructed the discourses expressed within the delivery of the physical and biological science curricula in a UK city school and post-16 college, interviewing and observing students and teachers. Her analysis leads her to warn against adopting simplistic essential stereotypes to explain gendered differences in engagement in science education: not all young women are put off by symbolically 'masculine' scientific disciplines and equally not all men are attracted to them. She contends that:

- Students' subjectivities can be influenced by their ethnicity and class as well as their gender.
- They are not fixed; students actively negotiate their subject positions throughout a period of study.

These observations suggest that there are alternative reasons for the physical sciences being dominated by a largely male elite. This in turn turns the focus onto the content of science curricula, and the need for a fundamental reconfiguration to widen the range of identity positions /scientist subjectivities on offer.

Faulkner, W. 2007, ''Nuts and bolts and people' - Gender-troubled engineering identities', *Social Studies of Science*, vol. 37, no. 3, pp. 331-356.

Faulkner bases her observations on ethnographic fieldwork in two UK offices of a building design engineering consultancy, shadowing six engineers in their daily work over a five week period. She concludes that:

- Two dominant identities exist uneasily side by side; an exclusive 'technicist engineering identity' and a heterogeneous identity which embraces the reality of the actual work. Many engineers oscillate between the two.
- The 'technicist identity persists because it converges with available masculine identities, allowing the full performance of the latter by recalling the stereotypes of 'hands on' work which is productive and powerful.
- This identity is problematic for women who more readily relate to the scientific base of engineering than its physical manifestation. Unlike many of their male counterparts, women have to create 'inauthentic' gender identities for themselves and hence their perception and experience of being 'real' engineers is likely to be more fragile than that of men's.

Faulkner calls for greater awareness of the 'gender trouble' produced by this restrictive stereotype of the technicist as the first step towards the inclusion of a wider range of identities in engineering.

Gaps

Theoretical and empirical research is needed to elucidate further the ways in which binary dualisms expressed through stereotypes, operate in different science disciplines. The insights provided by Faulkner (2000) and others in the field of Engineering could be replicated in other subjects. As part of this focus, pupils' and students' and employees' acceptance of stereotypes and adoption of gender appropriate identities should be studied for different age cohorts and from the perspective of ethnicity and socio-economic group.

Whilst there is a growing body of literature about gendered pedagogy, a systematic examination of gender-aware teaching both in terms of subject content and single-sex classrooms is needed to identify why and how this can further benefit girls and boys. As Cole et al (1994) have highlighted, more research is needed to look at the ways in which gender bias is being perpetuated in the following areas: access to curriculum; course design; teachers' attitudes and teaching styles; language; assessment issues; and the role of technology in teaching. Evaluation of the potential of a gender mainstreaming policy to counter negative hegemonic discourses and practices could be part of this work.

Career choices which spin off from experiences of learning are also relatively under-researched. In particular, findings suggesting that there is a lag between popular notions of scientific workplaces and their contemporary reality should be pursued to establish the level of understanding among pupils, parents, careers advisors and teachers about the range, content and remuneration of science occupations. Finally following Position 1 and the attempt to enthuse girls, a closer examination of the interplay between individuals' pleasure in science gained though interests, experiences and performances and their attitudes to science should be undertaken, both for girls and boys at school, and women and men studying at university

5.5. Science as a labour activity

Key Issues

Literature relating to scientific occupations, workplaces and the practice therein has mainly concentrated on issues of vertical segregation, and within this on women's trajectories, pay and rewards. Analysis of horizontal segregation has been within science disciplines, to explain why certain scientific occupations are being 'feminised'. There have been a few notable exceptions to this; studies which compare women's experiences of workplaces in different sectors of the labour market through the particular cultures and practices of different occupational groups and hierarchies (Crompton and Harris 1998).

Men and male careers in science are implicit in many studies as the 'norm' against which women's progress is charted. There are very few studies which explore men's preferences and experiences in science occupations, those that do, focus on the differences between women and men at particular stages of their early science careers as post-graduate students or post-doctoral fellows. These studies are concerned with individuals' perceptions of science subjects and educational choices and relate to the literature in Section 5.4. It is relevant to review them here, because unlike other disciplines the science labour market is heavily skewed towards paid work in higher education institutions, with clear pathways from study into work.

The majority of studies of scientific work examine professional non-manual occupations and within these the progression and careers of employees. There are a number of dominant conceptual models to explain women's place in science employment: most prominently the 'career pipeline' which has been developed exclusively to describe and explain women's career development in science. There are other metaphors applied from organisational theory to women scientists' experience such as:

- **'feminisation'** of some science occupations describing the disciplinary specialisms which female employees are deflected into. These jobs provide women with the ability to balance their public and private life. As the proportion of women grows in these areas, over time they can become perceived as inferior, peripheral, less well remunerated, and closed off from progression routes.
- **'mummy track'** the more limited career paths that are open to women when they become a parent.
- **'glass ceiling'** the phenomenon where women aspiring to more senior positions within an occupational hierarchical find their way blocked by informal practices such as male networking, or invisible promotion criteria based on gendered stereotypes
- **'token woman'** the success of one senior women is used as proof that the organisation is tackling gender inequality
- **'sticky floor'** describing women's experience of being promoted but losing out to men in the process, achieving a smaller grade advantage which maintains their lower position (and slower progress) within the hierarchy.
- '**dead men's shoes'** and **'gender queues'** refer to the slow rate of change within organisational hierarchies, where the trend for flatter management structures mean that promotional vacancies are limited and middle aged white men dominate the most senior positions until their retirement suppressing the opportunities of younger women and men.
- **'critical mass'** the proportion of women thought to be needed to shift the existing organisational culture
- **'iron cage'** relating to the self regulation or limits which women impose on their own progression, because they lack confidence in their ability due to a culture which undermines the value of their potential contribution.

Women's responses to the male dominance of the science sector, explored using patriarchal theory are a key theme in the literature. There are many local level studies which describe the

day to day harassment and indirect / direct discrimination faced by women and the strategies they adopt to cope, assimilate or rebel.

The experience and pursuit of 'work life balance' is another area of literature prevalent in the GSD which has been applied to women scientists. In the context of the sexual division of labour, women's reconciliation of motherhood and a science career has been described and explored in great detail in some of the science disciplines most notably medicine and dentistry. Many of these studies are interested in women's preferences and choices but fail to analyse in detail the systems and structures which act to constrain them.

The experience of combining caring and paid employment has prompted research into:

- the organisation of workplaces and design of jobs
- the demands of working long hours in science from the hours
- the requirement to travel as part of work
- the ability to be mobile - moving between employers and workplaces for career advancement

Men have figured in this research in two ways .Firstly as the partners of female scientists in dual career households, whose own ambitions and career trajectories can and do limit the choices of their female partner. Secondly research has recognised men's greater ability to meet the exigencies of a science job and career path because of the underlying assumption of the sexual division of domestic labour. Theorists researching workplace cultures have argued for the existence of a 'gendered sub text' in organisations which is based on the notion of the 'ideal' worker whose 24/7 availability to meet organisational demands and single-track attitude towards work is more easily fulfilled by men than women.

Research on informal gendered cultures, stereotypes and expectations became focused in the late 1990s on the changes in the wider context of science work; globalisation and rapid technological change. In higher education employment there was the development of managerialism and entrepreneurialism, which for science disciplines included the commercialisation of research outputs.

Analysis of the GSD provides the following description of the literature on which this section is based.

Number and percentage of publications

	n	%
Ireland	66	21.6
United Kingdom	356	34.2
Anglo-Saxon CS	**358**	**33.8**
All Cs	**1,483**	**32.6**

Relation with other topics

	%
Horizontal segregation	57.3
Vertical segregation	71.8
Pay and funding	29.1
Stereotypes and identity	49.4
Science as a labour activity	100.0
Scientific excellence	19.3
Gender in research contents	28.5
Policies towards gender equality in research	41.1

Average number of publications per year

	Average
1980-1984	2.8
1985-1989	3.0
1990-1994	3.8
1995-1999	11.8
2000-2004	24.2
2005-2007	38.0
2008-2009	8.0

Methodological approach

Empirical research	**%**
Non empirical research	35.2
Empirical research. Quantitative techniques	13.4
Empirical research. Qualitative techniques	38.5
Empirical research. Quali-quantitative techniques	12.8
Total	100.0
Approach	**%**
Conceptual	38.3
State-of-the-art	38.5
Compilation of statistics	17.9
Building gender indicators	2.2
Empirical research. Quantitative techniques	26.3
Empirical research. Qualitative techniques	51.4

Empirical research techniques

Quantitative techniques	**%**
Representative sample	44.7
Micro-data	37.2
Longitudinal/cohort	13.8
Multivariate analysis	41.5
Qualitative techniques	**%**
Biographical research	10.3
Case studies	24.5
Content analysis	3.3
Interviews	70.7
Observations	14.7

Research Areas

- Pipeline model of women's career progression, identifying women's career choices and constraints in the context of work life balance policies and the sexual division of labour.
- Discovering SET's dominant organisational culture: 'Today it is those organisations that specialise in scientific activities that have been able to hold on to a culture of masculinity so tenaciously' (Takruri-Rizk et al 2008:298)
- Structure of work and its associated gendered sub text: Defining the 'ideal' SET worker based on male characteristics and physiology which have been normalised (Acker 1992).
- Global, national and local pressures introducing managerialism and commercialism.

Research Questions

- How useful / appropriate is the pipeline model in explaining women's career decisions?
- How do women experience male dominated scientific workplaces? What mechanisms have they adopted to fit in / cope?
- How has the development of managerialism in Higher Education affected women's experience of work and progression?
- What are the working practices of scientific institutions and the extent of family friendly working on offer?
- How are male norms embedded into organisational structures and cultures?

Research Approaches

Research on science as a labour activity demonstrates distinct developments over the last three decades. In the 1980s there are few studies looking at gender and science at an organisational level, those tackling the subject are forerunners of Positions 2 and 3 and show remarkable insight, of particular note and subsequent influence is Cynthia Cockburn's (1983) work on men's control of technology and of male privilege in the workplace.

Organisational practices and responsibility for equality in employment came to prominence in 1990s following significant legislative changes. This development may also be linked to the movement of many feminist activists and practitioners from industry into academia. These new academics were able to reflect on their treatment and experiences, and gained the tools in the academe with which to analyse it. Literature reflecting Position 2 explores in detail women's experiences at local level and uses this empirical data to refine and critique the linear progression described by the pipeline model (Section 2.2.4), to provide evidence of women's disadvantage relative to men due to the sexual division of labour. Explicit resistance and overt strategies in male dominated workplaces are also revealed using an analysis of patriarchy. By 2000 the need to re-examine all aspects of organisation life and that of its products for gender bias has been put firmly on the research agenda. The new investigation of gendered sub-texts applied successfully in some science disciplines (particularly by Faulkner in Engineering) provides greater clarity of who are the winners and losers in the structural changes to organisations being brought about by global, national and local economic pressures.

Findings

Organisational barriers to women's career development – pipeline model. Research focusing on the science career pipeline falls into three areas. First, there are a group of publications (most notably in the fields of dentistry and medicine) which adopt the model uncritically and provide empirical evidence which support its proposition that women choose to halt their progress or even exit from a career trajectory all together when they have a family (Newton and Thorogood 2000, McEwen and Seward 1989, Shaw 1980, Field and Lennox 1996, French et al 2006, Wakeford and Warren 1989, Williams and Cantillon 2001, Goldacre et al 2002, Lambert et al 1996, Ward 1982). One of the startling findings among this literature is how early on in their careers women are anticipating family formation. Field and Lennox (1996) found that many first and fifth year female medical students had based their choice of clinical attachments on the posts and which would best accommodate their desire to have a family life in the future.

A second group of publications, across all science disciplines, flags up the mismatch between a linear career path premised on incremental qualifications and the reality of women's professional lives. The model fails to explain women's experience in some occupations. Caven has shown that in architecture women working non standard hours, outside a conventional organisational setting, are not necessarily in a 'career sideline' - but the opposite. Women report that it has been beneficial to their professional development and enabled them to combine non-

work activities better (Caven 2006a and b). Likewise women who return to their career in science after a career break to raise a family, or come to science education as mature students, often with a family already established, are not a homogeneous group who experience equal disadvantage (Equalitec and University of Bath 2005). The length of their break from employment is a significant factor in their ease and level of re-entry, so too is their level of confidence in their ability to surmount new changes in the industry and assurance that the culture to which they are returning is sympathetic towards people with family responsibilities (Hughes 2002, Panteli and Pen 2001, Morley 2007).

A third body of literature highlights the gendered nature of the pipeline model and its apparent objective measure of qualification (Hodgson et al 2000). These argue that the model gives too much importance to individual aptitude and determination to move forward, missing an analysis of the larger structural and social factors which pattern women's lives inside and outside the organisational context. Corcoran-Nantes' and Roberts' (2007) study suggests that even women who start strongly on the qualification route and appear to be potential high flyers are still being obstructed by harsh and often patronizing workplace cultures with demands for time commitments which are incompatible with life outside work. As a result women can find themselves deflected to a 'branch' of the pipeline, into peripheral jobs within the skilled mainstream or left behind in the more routine functions of the professions as their male counterparts conjugate in new areas of work (Gammie and Gammie 1997). Evetts (1994) identified that female engineers constructed alternative careers paths away from people management roles to technical specialist careers – in this way they could manage the hours more easily as their daily workload was under their control and more predictable. Simpson (1994) suggests explanation for why the pipeline model continues to be popular. She found that women themselves are not always aware of the external barriers to their progression, attributing their success solely to internal qualities. In an environment where women continue to be such a minority, survival may necessitate the adoption of male values and result in their assimilation (also Powell and Dainty 2006).

Women's experience of the male hierarchy. Feminist research into a variety of male dominated science organisations has identified a number of sexist practices which work against women. Men's adept use of 'social capital' through informal networks and relationships gives them greater access to new ideas and professional partnerships (Etzkowitz et al 2000). Insider knowledge of the informal rules is vital for progression and self promotion. Yet women are excluded from participation because the network is built around male homosociability, or out of work contact in evening hours which clash with home life (Griffiths at al 2007, Jensen et al 2005, Fletcher et al 2007). Watts 2007 found that the ways women cope with the competitive and conflictual nature of male culture in the construction professions was to become complicit, giving up an overtly feminine identity. Faulkner has made a similar observation relating to women engineers. (Faulkner 2005). Cockburn's work has been hugely influential in demonstrating how in manual trades men have accomplished a separation and elevation of the status of their work from that of women's by associating it with technology and modelling tasks and workloads on male physiology (Cockburn 1985a). Bagilhole in the same way has been a central author on harassment in the workplace, conceptualising the different degrees of intimidation enacted by men in male dominated environment and its effect on professional women, particularly in the higher education sector (Bagilhole and Woodward 1995).

Cockburn, C. (1985) *Machinery of Dominance: Women, men and technical know-how*, Pluto Press: London

Why are there so few women engineering, technicians and craft-workers? Cockburn was one for the first academics to apply a theory of patriarchy to engineering: to argue that the reason is not due to women's lack of ability or interest, but that men strive to retain the power that comes from controlling technology. Her examples are drawn from the workplace, focusing on organisational practices and policies.

She shows that hierarchies, sub-divisions and union affiliation in the workplace, along with control of training and grooming processes enable men to keep themselves separate from and superior to women workers. Consequently, women remain in lower paid operative positions while men continue to dominate technologist roles.

There is a distinct body of literature falling under this heading which looks at women in science who work in the academy. Finch (2003) has argued that higher / further education institutions should be treated as a phenomenon in their own right rather than another illustration of a labour market sector. She considers that inequality is endemic in these institutions since it is replicated, reinforced and sustained by its many different, yet interdependent, occupations and hierarchies. Academics are an unusual profession in that an individuals' merit is not solely evaluated by their employer but also by an external audience of academic peers, editors, funders and students/ patients. The tradition of academic autonomy has meant that the human resources function of universities is under developed meaning that protection afforded to under represented groups in other organisations workplaces is not as robust (Wilson 1999, Ledwith 2000).

Evetts, J. (1996) *Gender and Career in Science and Engineering*, Taylor & Francis: London

This book focuses on the careers of professionally qualified, female scientists and engineers in large industrial organisations. Among many aspects covered, Evetts considers the difficulties experienced by female engineers their workplaces; particularly their experience and awareness of gender, and their attempts to manage relationships with co-workers, managers and clients.

Evetts found that difficulties are not associated with the culture of engineering itself or women's feelings about and experience of using technology and generating technical solutions. Problems of career development lie with implicit gendered expectations of employees and the processes and structures for promotion and implementation of organisational policies.

A distinct preoccupation of research into women's position in the academy has centred on the contemporary context of managerialism which has been introduced by successive governments in the UK and Ireland to improve efficiency and quality of these institutions whilst increasing their capacity for student numbers (Halford 2003, Brooks and MacKinnon 2001, Crompton 2001, Deem 2003, Deem and Brehony 2005, Barry et al 2003, Deem at al 2000). Restructuring in the public sector has been shown to disadvantage women at certain stages of life and career, for example women with caring responsibilities who do not have flexibility in their lives outside work to make a commitment to 'long hours', the spill-over of work at home via remote technology or out-of-work study to meet new qualification expectations (Acker 1992). Looking at science occupations specifically, Leonard has studied the type of posts created through restructuring the management hierarchy and concluded that a focus on finance, commercialisation and facilities management have strong masculine associations which have had negative consequences for women's promotional prospects (Leonard 1998). Others have looked that the knock on effect on workplace culture and concluded that managerialism can

give rise to a 'bully-boy' culture in which men fair better than women (Leathwood 2000). Among the new range of professional identities created by managerialism, women in middle range positions wanting to advance their careers have been left with fewer choices of positive identities (Barry et al 2006).

Structure of science jobs and the 'ideal' worker. Issues such a 'long hours' culture entailing presenteeism, the 24/7 manager who is constantly 'on call', or the geographically mobile executive (in search of promotion, or operating internationally) are phenomena which have been observed in the science disciplines in higher education (Halvorsen 2002, Ward 2000, Griffiths et al 2007, Ackers and Gill 2005) and in technology based SMEs (Wynarczyk and Renner 2006). More women than men are unable to make a commitment to the exigencies of this type of senior post as they try to juggle their commitment to work with greater domestic responsibilities. As the Women in Work Commission (2007) concluded it is the structure of the posts rather than the individuals filling them who are at fault, since this way of working has been shown to be neither productive nor healthy. The Commission recommended the development of more part-time senior level positions which would enable bother women and men to achieve a greater work life balance. The consequences when it can't be made to work is women's flight from science careers to occupations which offer more flexibility such as teaching, as Smeaton et al (1997) found. Some women make a deliberate decision to 'tread water' staying at a level which is below their proven or predicted potential in order to maintain a workable balance (Evans et al 2007 Glover 1999).

Linking back to the discussion of stereotypes and identity, organisational theory has attempted to explain women's lack of 'choice' about family and work in terms of the existence of a 'gendered sub-text': Gagliardi (1986) described organisational 'talk' and organisational discourses as the primary means by which scientific institutions reinforce stereotypes. These stereotypes describe characteristic images of the kind of people that should occupy senior positions (Kanter 1977). The image is one of senior managers with subordinated personalities, who are emotionless 'ideal workers' (Schwartz 1996) without domestic commitments. The use of the male pronoun in engineering when referring to managers is an example of how the sub-text operates to render women invisible and inappropriate (Faulkner 2000). Women who do reach higher levels are therefore labelled as 'tokens' (Phipps 2002, Rodd Bartholomew 2006) and many women are put off even trying.

There is anecdotal evidence that the SET manual trades offer women more ways of achieving work life balance through self employment and attract women for this reason. However, conversely, the traditional male pattern of full time training hours in manual trades is not flexible and poses problems accommodating children's or other dependent's needs.

Gaps

Research to refine the pipeline model of women's careers should be pursued to establish the exit points and branches in different SET disciplines. This evidence would assist the development of targeted policy initiatives. To extend the current research on work life balance and women's choices a link needs to be made to the phenomenon of 'working below potential', building on the work of Glover (2005) and Evans et al 2007. Qualified women employed in other sectors have identified distinct points in their careers when they could not consider taking on the demands of the more senior job and chose stay in jobs which did not challenge them for a period of time until their domestic circumstances changed. The difficultly of starting up their career progression again after domestic demands have lessened is a further issue. This understanding should be applied to women working in science to uncover the extent of squandered potential and to inform and support appropriate actions by employers. A further dimension of this focus is managers' conceptualisation of part-time work and the tension with the notion of an 'ideal' (full-time) worker. Research into a range of different types of employers' perspectives is needed so that a picture of part-time work and progression can be drawn between difference SET disciplines.

The experience of professional women navigating male dominated workplaces and cultures is well developed. However almost unknown is the ways in which different groups of men experience this environment. As Connell (1987) has shown workplaces are constructed of

hegemonic, complicit and subordinated masculinities which individuals must choose to ally with. The choices which men make and the ways in which masculine cultures are changing or can be changed is an area for ongoing research.

The experience and career development of women working in manual trades and as self employed individuals is largely absent from the literature. The research is very focused on labour activity the academy, perhaps unsurprisingly given the difficulty of gaining access to any but the most enlightened private employers. This is another deficiency which should be addressed.

An evaluation of measures, projects and programmes put in place to support women returners and to retain women scientists need to be undertaken. Also the ways in which science companies/ departments have responded to new legislation on flexible working and gender mainstreaming.

5.6. Scientific excellence

Key Issues

The demonstrating the achievement of scientific excellence is arguably the biggest hurdle to the most senior and prestigious positions in the scientific hierarchy. It is also a significant determinant of pay. Its definition and the process of assessment are therefore contentious and have increasingly been scrutinised for gender bias, as debates about the neutrality of science as a whole have developed and women's vertical segregation has been highlighted.

The debate in the UK and Ireland has focused on achievements by academics in their discipline of expertise working within university organisations. Research in the UK has pointed out the historical homosociability and homogeneity of management structures in universities, resulting in intimate connections between men's interests and managerial objectives. Male cultures at institutional and departmental level become normalised and no process remains neutral despite sector-wide commitments to equality of opportunity. The achievement of scientific excellence rests on assessment procedures and systems. Hearn and others have pointed out that having men as chairs of evaluations panels, editors of journals, designers of criteria and the majority of applicants not only ensures their greater reward but also privileges the knowledge which they produce (Hearn 2001). This is particularly visible in science disciplines such as Engineering where men outnumber women in the greatest proportion.

Responding to bias in scientific systems of rewards and reputation, the European Commission established the European Technology Assessment Network on women and science ETAN in 2001 to prepare the report *Mainstreaming Gender Equality in Science in the European Union*. The report called for the application of gender mainstreaming tools in science institutions to gender proof systems, use positive action measures to redress indirect discrimination, and to train dedicated practitioners – 'watchdogs', to sustain a level of gender awareness. Hearn (2001) and others have gone further in recommending:

- more women and fewer men participating in evaluation processes and mechanisms (criteria setting, scoring, refereeing)
- target numbers of women on decision making bodies and panels
- training to ensure that male managers are gender aware and accountable for their departments' / organisations' equal opportunities commitments
- increasing the numbers of female funding applicants and research directors through positive action measures,
- recognise and address through assessment criteria the advantages conferred on men of male networking in the formulation, conduct and evaluation of research,
- recognise and address through assessment criteria the advantages conferred on men of normalised working arrangements which benefitting from the sexual division of labour, rely on full time, long hours.

Analysis of the GSD provides the following description of the literature on which this section is based.

Number and percentage of publications

	n	%
Ireland	50	16.3
United Kingdom	167	16.0
Anglo-Saxon CS	**169**	**16.0**
All Cs	**900**	**19.8**

Relation with other topics

	%
Horizontal segregation	56.8
Vertical segregation	56.8
Pay and funding	28.4
Stereotypes and identity	51.5
Science as a labour activity	40.8
Scientific excellence	100.0
Gender in research contents	40.2
Policies towards gender equality in research	44.4

Average number of publications per year

	Average
1980-1984	0.8
1985-1989	1.4
1990-1994	1.4
1995-1999	4.6
2000-2004	14.2
2005-2007	14.0
2008-2009	7.5

Methodological approach

Empirical research	**%**
Non empirical research	46.2
Empirical research. Quantitative techniques	11.8
Empirical research. Qualitative techniques	26.0
Empirical research. Quali-quantitative techniques	16.0
Total	100.0
Approach	**%**
Conceptual	45.6
State-of-the-art	36.7
Compilation of statistics	13.6
Building gender indicators	4.1
Empirical research. Quantitative techniques	27.8
Empirical research. Qualitative techniques	42.0

Empirical research techniques

Quantitative techniques	**%**
Representative sample	57.4
Micro-data	51.1
Longitudinal/cohort	8.5
Multivariate analysis	48.9
Qualitative techniques	**%**
Biographical research	8.5
Case studies	22.5
Content analysis	4.2
Interviews	64.8
Observations	25.4

Research Areas

- Assessments in education producing gendered advantages
- Gender bias in methods of judging excellence through publication and citation in HE
- Ingrained male norms in managerial cultures resulting in gendered performance appraisal outcomes
- Gatekeeping - its actors and their practices

Research Questions

- Do different assessment methods favour pupils of different sex?
- To what extent can assessment measures of excellence in the academe be objective? Where and why does gender bias creep in? What methods can be used to eliminate bias?
- Do different managerial practices normalise an 'ideal candidate / employee' which advantages men?
- Who are the gatekeepers of excellence? Do they operate in ways which privilege male knowledge? Can women be gatekeepers?

Research Approaches

The research on gender bias in the achievement of scientific excellence has been mainly produced in the last decade (Position 3). It covers three areas: first, the *validity of particular procedures / structures* which are used to assess excellence in individual work ranging from assessments of students abilities, the award processes for research funding, fellowships and prizes and the methods of judging originality and merit in academic publishing. Second the relative *accessibility of the measures of success* based on the numbers of women and men attaining the highest accolades and an analysis of the barriers which prevent women from achieving more. Third, the *influence of gatekeepers* and their impact, both positive and negative, on producing equitable outcomes.

Findings

The literature which makes a relevant contribution to this subject has mainly been written in the last ten years and is concerned with: the assessment of academic merit; the criteria applied to academic advancement; and the people and structures which administer the system.

Literature examining procedures for assessing excellence in individual work has tended to look at individual parts of the whole, rather than on the culmination of judgements over a person's lifecourse / career. There is more literature which considers the ways in which expertise is judged during the different stages of education/study than during employment. The gendered nature of examinations versus course work assessment has prompted a large debate. Elwood (2005) speaks for many academics in arguing that assessment in universities pays a complex role in defining gendered differences in performance: different styles of examinations and types of questions can define achievement, likewise coursework assessments can benefit certain gendered approaches to learning (also Gammie et al 2003). For example Bransky's and Qualter's (1993) work on the assessment of students' understanding of concepts in physics found that the context in which the concept was presented, rather than the intrinsic complexity (and hence difficulty) of the concept itself, produced gendered outcomes. Pirie (2001) observed that assessments which reward risk-taking and a grasp of the big picture confer an advantage on boys, whereas those which favour systematic consistent attention-to-detail answers favour

girls (Woodfield and Earl-Novell 2005). Other contributors whilst acknowledging the significance of the assessment methods argue for maintaining a holistic picture of the factors which affect educational outcomes, Stobart (1992) says they cannot be divorced from the different experience and expectations of pupils and teachers.

Research investigating the measurement of academic quality by qualified scientists does not distinguish between or contrast the performance of employees in commercial, university and university-related research centres. The majority of the publications in the GSD are concerned with assessment of university departmental scientific achievement. As discussed in the previous section, academics are a unique group of employees in that their reputation and ability is judged by their peers outside of their employing institution. Peer review of the originality and value of new or proposed contributions to knowledge, both empirical and theoretical, is the central operational standard by which a 'fair' assessment of quality is reached. However an increasing number of academics have questioned the assumption of objective judgement which underpins this standard arguing that factors other than scientific quality may influence the reviewers' pronouncement on research papers, fellowships or grant applications. Gender, personal familiarity (or enmity) and country of origin/ native English have been shown to affect reviewer behaviour (Budden et al 2008, Tregenza 2002). As research highlights, despite providing greater credibility in the decision, double-blind review (in which the identities of author/ applicant and reviewer are not revealed) is not uniformly practiced by funding bodies or journal editorial boards. Gender bias which creeps in has been shown to mirror the sub-text of the funding organisation, incorporating stereotypical images of the 'ideal type' candidate, perhaps predictably perhaps in the image of a white male (Delamont 1989). Foschi (2004) has collected evidence of gender-based double standards in the judgement of competence; wherein women's past performance is judged more harshly than that of their male peers and their competence/ability represented as less significant in scenarios where their output is the same.

Within the higher education sector there are a number of different criteria against which an individual's academic performance is defined and quantified, and on which their promotional prospects are based (Forster 2001) these include:

- degree class
- volume and quality of published output
- citation of work
- internal appraisal
- securing external funding
- winning scientific prizes / fellowships

Each of these areas has been investigated for gender bias, with some studies looking explicitly at science disciplines. The bias has not been found to be malicious in all cases. Earl-Novell's and Woodfield's (2006) study of women's under-representation in student cohorts achieving first class awards at university reviewed hypothesis which assumed gender linked cognitive / personality traits, subject dependent levels of achievement linked to gendered socialisation and the compositional effect of men being concentrated in first-rich science subjects. Their analysis concluded that the 'gender gap' was more likely to be the result of the latter effect than inherent differences in ability or teaching practices across disciplines (also Farsides and Woodfield 2007 Simonite 2005).

The previous section addressed the issue of indirect discrimination which women face as a result of the institutionalisation of a male style working pattern as the 'norm' which puts greater pressure on some women (in particular those with caring responsibilities) to meet expectations of long hours commitment and geographic mobility. Another dimension to this working pattern is its associated output; the expectation that each academic will produce a quantity of peer reviewed publications based on research. The volume of work expected is standardised by government league table criteria relayed to academic departments via instruments such as the Research Assessment Exercise in the UK, a quinquennial peer review based audit system designed to assess the international reputation and academic quality of research groupings, whose score determines levels of central funding. Penas and Willett (2006) looking at information science research have demonstrated that male academics publish significantly more papers then their female counterparts despite there being a gender balance in the

employee profile. This is linked to men's ability to commit more hours to their job and the uninterrupted nature of their endeavour (very few men take up the opportunity of career breaks to raise children or care for dependents). Differences in citation has not been as extensively researched as academics' publication records, however this measurement is dependent on the perception of the entire external academic community and Penas and Willett found no apparent gender difference in the frequency of citation (Penas and Willett 2006).

The new managerial culture of many Higher Education and Further Education institutions has encouraged the adoption private sector practices, one of these being employee appraisal and a second the commercialisation of the university's research output to generate income. Whilst there is no Anglo Saxon literature in the GSD which examines either practice in relation to women scientists, there are several studies about female academics' experiences in general. These tell the same story as the literature on publication and reputation building; that the power relations operating in appraisal processes and the commercialisation and pursuit of external funding normalises a highly competitive role model focused on producing quantifiable outputs (Bagilhole and Goode 2002). Women's efforts to gain recognition of the alternative ways in which they contribute to academic life by putting together different discourses of achievement face considerable opposition or non attention (Thomas 2007). Rees (2004) has observed that many scientists including women are quick to maintain that the processes in science are neutral and merit-driven and that its inherent 'objectivity' means that science cannot be gender biased. In the face of the numerical evidence this could be described a 'false consciousness' and also explain why so little research has been undertaken in these area.

A final area of the literature is concerned with the 'gatekeepers' of excellence; consisting of external funding bodies and internal, male dominated, institutional hierarchies. Much has been made in the policy field of women's' under-representation on the executive boards of awarding panels, and the extent to which this disadvantages female applicants which is addressed in Section 5.7. Within universities a variety of mechanisms have been identified, not all specifically in science disciplines, which mitigate against women's scholarship being valued or developed as much as men's, these include the practices of: 'grooming' young researchers in the image of the existing hierarchical order; the daily practice of senior male academics not reading, recommending or valuing the work of the women they line manage (Hearn 2001); the exclusive access to research cultures, ideas and partnerships conferred on men by their networks (Deem and Brehony 2000, Fletcher et al 2007); and evidence of more supervision problems, particularly bullying, experienced by women in male dominated subjects (Royal Society of Chemistry 2008).

Finally, a small number of studies have researched women's complicity in upholding a system which is biased and unfair. Proponents of building up a critical mass of women into science (Powell and Dainty 2006) in order to fundamentally change the value system and promotion processes highlight the importance of finding gender aware women rather than those who exhibit the 'false consciousness' of women scientists identified by Rees (2004), Ledwith (2000) and Phipps (2006). Others point out that women's lack of confidence in their own ability can often act as a form of gatekeeping, as women are more likely than men to doubt the value of their work causing them to delay application for promotion or prevaricate about putting their findings forward into a more public arena to gain recognition (Evetts 1996).

Gaps

Whilst a comprehensive study of the gendered nature of research funding allocations has been undertaken by Millard and Ackers (2008) (discussed in Section 5.3) , this report should be augmented with further empirical research to demonstrate the discriminatory nature of practices and cultures and the organisations which uphold them, in order to provide a focus for policy intervention. Routine regular collection of statistics disaggregated by sex, at institutional and national level, about funding awards, prizes and fellowships should be made publicly available on an annual basis.

Research on the effect of higher education managerial practices in normalising a highly competitive role model focused on producing quantifiable academic outputs and therefore more suited to male career paths (Bagilhole and Goode 2002) should be extended to all science

disciplines, where cross discipline comparisons can be made. Within this work, women's alternative contributions to academic departments (for example their pastoral and administrative roles) should be recorded and their value debated. Further research is needed to address the gap in the literature about the processes of judging academic quality and performance of employees in private commercial companies.

Women's awareness of a gendered bias and hence their decisions about where and how best to deploy their effort for maximum return has not been sufficiently studied as part of the 'pipeline' model. These studies should include both gender-aware women and their more 'traditional' female counterparts. Longitudinal research is needed to establish the culminative effect of gender bias in the system of assessing excellence over an individual's life time. To identify at which points harm to a person's career trajectory is most likely to occur in science disciplines, again this work can be related to the 'pipeline' model.

5.7. Gender in research contents

Key Issues

This topic is pivotal both for debates about excellence in science and the development of equality policies in science. Its starting point is the acknowledgement that science is a social activity which takes place within a social structure (Buckingham-Hatfield 2000). This simple statement turns on their head the ontological and epistemological positions which have guided scientific work for the last century. It suggests that our understanding of what can be said to exist and the ways we can categorise or make sense of similar phenomena is socially constructed and therefore transmutable over time, rather than fixed and essential. Undertaking research from this perspective demands a reflexive view of what it is possible to know, since the questions and observations of individuals will be subject to their own peculiar set of constructed knowledge affecting what they see and how they interpret this information. Again, epistemology which recognises situated knowledge is in opposition to traditional science which upholds individuals' ability to remain objective and distanced from their topic of study and their confidence in the ability of experimental methods and repeated testing to establish 'the truth'. Juxtaposing gender and science immediately introduces one important bias in the pursuit of scientific 'truths'. Feminists have argued that the unequal power relations between women and men in the scientific academy has resulted in scientific agendas which privilege male interests, not only in terms of which topics are prioritised for study but also affecting the questions (and hence answers) that are posed.

Analysis of the GSD provides the following description of the literature on which this section is based.

Number and percentage of publications

	n	%
Ireland	133	43.5
United Kingdom	337	32.3
Anglo-Saxon CS	**340**	**32.1**
All Cs	**1,434**	**31.5**

Relation with other topics

	%
Horizontal segregation	39.4
Vertical segregation	36.8
Pay and funding	14.1
Stereotypes and identity	58.8
Science as a labour activity	30.0
Scientific excellence	20.0
Gender in research contents	100.0
Policies towards gender equality in research	42.9

Average number of publications per year

	Average
1980-1984	1.8
1985-1989	3.0
1990-1994	6.2
1995-1999	10.2
2000-2004	22.8
2005-2007	31.0
2008-2009	13.5

Methodological approach

Empirical research	**%**
Non empirical research	59.7
Empirical research. Quantitative techniques	8.2
Empirical research. Qualitative techniques	19.1
Empirical research. Quali-quantitative techniques	12.9
Total	100.0
Approach	**%**
Conceptual	57.4
State-of-the-art	48.5
Compilation of statistics	15.3
Building gender indicators	4.4
Empirical research. Quantitative techniques	21.2
Empirical research. Qualitative techniques	32.1

Empirical research techniques

Quantitative techniques	**%**
Representative sample	50.0
Micro-data	37.5
Longitudinal/cohort	4.2
Multivariate analysis	43.1
Qualitative techniques	**%**
Biographical research	11.0
Case studies	36.7
Content analysis	11.9
Interviews	64.2
Observations	24.8

Research Areas

- Male bias in the scientific academic tradition
- Rcognising situated knowledge and the challenges and advantages of a diverse scientific community of contributors

Research Questions

- What type of contributions have women made throughout history to advance of scientific knowledge?

- What are the implications of scientific ontology and epistemology of recognising male bias?

- What are the advantages of incorporating a greater range of situated knowledge in scientific research? How can this be done in practice?

Research Approaches

The research publications relating to this topic can be divided into four distinct areas:

- reclaiming the history of women's contribution to scientific advances which has been overlooked or poorly recorded and recognised;
- identification of male bias and arguments for the application of gender aware epistemology in scientific endeavour;
- debates about the need for diversity among the science community to ensure the incorporation of different situated knowledge;
- methods of undertaking gender-sensitive science, borrowing from insights of other disciplines, most notably social science.

The areas are listed in the order in which they have developed over the last three decades. The first is closely linked to the writings of the women's movement in the 1970s and 1980s when debates about women's place in public life were still contentious and evidence was being gathered in many arenas to support the argument that women's ability was equal to that of men's, and that they were able to make important contributions to life outside the home and in areas in which they were under-represented. The development of a feminist epistemology in the late 1980s, in works such as (Fox Keller 2000) have impacted on all academic disciplines, and in science provided an important means to countenance arguments about male bias in science which had troubled practitioners over the previous decade; evident in their writing about teaching practices and girls reception of science subjects in school. Originating in social science it was perhaps automatic that solutions should be sought from these disciplines, particularly sociology and social policy. Organisation theory introduced debates about the ways in which patriarchy operates in hierarchical settings and the direct and indirect ways in which a hegemonic culture is maintained and alternative perspectives are sidelined. Following on from the promotion of equal treatment practices to level the playing field for disadvantaged groups (and their agendas) came advocacy for diversity - the active recruitment of under-represented individuals to bring a greater range of viewpoints and abilities into the workplace. The ultimate aim was to produce a 'mosaic' which incorporated more talent and was capable of greater creativity. This literature was influenced by the hastening movement to globalised production and is not exclusively focused on women but also on people of different ethnicities and races.

What a commitment to gender equality in scientific research means in practice, is at the heart of the final area. Much of the literature concerned with practices which breakdown horizontal and vertical segregation for women and other under-represented groups in the scientific hierarchy avoid talking about men and men's role. There are far fewer contributions about how the (male academic) scientific community would behave and how its structures and processes would change if it were to embrace and enact gender equality. Jeff Hearn's work on men and masculinities is one of these lone voices (Hearn 2001). As in other topics, literature relating to Gender in Research Context is almost exclusively concerned with SET issues in the Higher Education rather than applied to private research settings

Jeff Hearn's work is ground breaking because he focuses on men as the missing part of the study of gender. A key proponent of Critical Masculinity Studies CSM in sociology he highlights the insights and developments in his own discipline which have to some extent occurred in the

natural and technological studies but could be applied more rigorously to greeter effect. He advocates:

- Explicitly recognise men as having a gender rather than treating their presence and research as 'the norm' against which women's work and progress is measured.
- Apply a social constructionist understanding of gender identity to men and their practices in the academy in order to recognise different forms of masculinity which change over time. Part of this analysis should incorporate Connell's spectrum of hegemonic complicit and subordinated masculine positions which aware that masculinity is not the only social division in play, class, ethnicity and sexuality affect men's position along the spectrum and in turn their openness to an alternative feminist epistemology.
- Foreground the role of the researcher and their impact on framing scientific areas of research and what is found there. This requires individual male researchers to question their epistemological / ontological starting point, acknowledging the politics of their area of study (i.e. how does it impact on gender relations in the real world) and their own geopolitical position in relation to their subject matter (i.e. the power relation between themselves as researcher and the researched). Hearn advocates the development of research in which the topic and the researcher's standpoint are reflexively considered in an emancipatory context.

Others in a similar line of argument have highlighted the paucity of scientific research findings that can result from 'gender blindness' citing examples of research undertaken with only male participants to produce medication which is assumed to be suitable and safe to be used by women, with disastrous consequences. The underlying conclusion being that good research is gender sensitive.

Findings

One dimension of addressing women's absence from science has been to write women back into the history of science, providing evidence of the significance of the contribution of known female scientists, as in the case of Lady Mary Montegu (smallpox inoculation), or documenting the lives of those whose endeavours had previously gone unrecorded as with Ada Lovelace (computer science). Alic's work is a typical example of this genre of research, published by the women's press and inspired by a radical feminist intent to set in place a precedent for women making great strides in contemporary scientific research (Alic 1986).

It is only a small step from reclaiming women's past work to asking what male dominated science may have missed, and what questions and priorities a women's agenda might consist of. The development of feminist standpoint theory in sociology coupled with legislation were hugely influential problematising the design of scientific research which had failed to include sex differences, producing poor results particularly in the area of clinical and laboratory medicine (Holdcroft 2007a).

A wider examination of male bias in the ways in which scientists conduct and discuss their work has followed, (Keller and Longino 1996, Christie 1990, Olson 1990, Buckingham-Hatfield 2000). Theorists have split their attention between science education and scientific research. One group have studied the effects of applying an 'objective' scientific paradigm in education and its impact on teaching styles, content and outcomes for girls and boys (Dunne and Johnston 1992 and Cronin and Roger 1999 , Mahony and Van Toen 1990) while others have interrogated the inventions of science (Wajcman 1991, Plows 2008) or the practices of particular areas of expertise (Julie 2007, Bjorkman 2005). These publications are not numerous and in contrast with the other topics are conceptual and philosophical in aim and method rather than empirical.

The origins of standpoint theory, provided by Marxist feminist work about consciousness and identity politics expressed through social movements, has predisposed its application to the perspectives of all marginalized and oppressed individuals whose insights if accessed effectively could help to create more objective accounts and knowledge of the world. It supported critiques of male bias levelled at the science community and heralded a call for greater diversity of participants. The term 'diversity' entered sociological parlance in 1990s

within organisational and equality theory to express the post-structural notion of difference within and between groups. In the UK and Ireland differences initially included gender, ethnicity and race, and disability and more latterly (through the influence of the European Union) sexuality, religious belief, socio-economic group and age. The research in the GSD which has addressed 'diversity' has focused on the possibilities of achieving a mix through a better gender balance of the workforce (Adam et al 2008) and an awareness of different gendered users of scientific products (Clegg and Trayhurn 2000, Oudshoorn 1994), there are a few notable exceptions to this which look at the advancement of *different groups* of women incorporating perspectives such as race and ethnicity (Hennessy and Dunham 2002). The diversity perceptive whilst allowing for the inclusion of a wider range of situated knowledge to the betterment of research formulation is not without its critiques. Deem and Morley (2006) have argued that a great emphasis on contribution recognition rather than redistribution of resources between groups means that the pursuit of gender equality using a diversity paradigm may result in a depoliticisation of equality commitments and a 'watering down' of impact. This literature has an obvious relationship to the topic on policy approaches.

As well as a concern to diversify the academic community, other commentators are keen to mainstream a diversity perspective into the selection of research subjects, to ensure that clinical and laboratory practice is sensitive to gender. For example, Holdcroft (2007a) considers how a systematic failure to include sex differences in research study design can lead to flawed results in evidence based medicine, A key recommendation is to import insights from other disciplines, most notably the methodological and ethical approaches of social science (Lykke and Braidotti 1980, Hearn 2001). This area of literature is not very developed.

Finally, research has been undertaken into the stereotypes embedded in the physical world which uphold a perception that women's relationship to technology is as a passive user rather than a creator. (Lohan 2000, Wajcman 1991, Blickenstaff 2005, Faulkner 2001, Margolis and Fisher 2002, Phipps 2002). Theorists of technology have argued that a powerful dualism has been institutionalised through technology's association with capitalism and male power (Fox Keller 1982, Harding 1998, Lohan 2000) and gadgets with 'modern masculinity' (Cockburn 1985a, Gorriz & Medina 2000). There are a number of notable studies which illustrate these associations, for example Cockburn and Ormond's (1993) history of the micro-wave oven and Brosnan's (1999) study of school children's perceptions of the 'typical' computer user. Town Planning & Surveying is another area of science where these analogies have been drawn. It has been argued that the physical layout of cities is based on male rather than female patterns of use (Little 1994) due to the fact that men predominate amongst urban decision-makers (Greed 1994). Engineering, at the heart of industrial production, transportation, irrigation, housing, sanitation, health care, energy, pollution, surveillance and environmental control, produces similar gendered disadvantages for women (Frank Fox 2006).

Town planning and studies of the built environment, notable contributions:

- Buckingham-Hatfield, S. (2000) 'The making of science: it's a man's world' *Gender and Environment* Routledge: London pp11-32
- Booth, C. & Gilroy, R. (2001) 'Gender aware approaches to local and regional development: better practice lessons from across Europe' *Town Planning Review* 27(2), 217-242
- Greed, C. & Reeves, D. (2005) 'Mainstreaming equality into strategic spatial policy making: are town planners losing sight of gender?' *Construction Management and Economics,* Special Issue on Diversity and Equality in Education, Vol 23, Issue 10, pp1059-1070

Within UK Town Planning, a practitioner movement emerged in the 1990s aiming to make policy and planning guidance gender aware: to recognise the different uses women made of public spaces and transport. This has developed into an academic critique of the 'gender blind' nature of practice and the pursuit of better practice examples.

Gaps

As part of efforts to raise awareness of gender bias in the practice of science, documentary analysis of women's past achievements in science should be continued to produce a more accurate and enriched account of historic scientific development. This could include women in the scientific teaching profession as well as in research.

Research which has addressed 'diversity' in science (education and occupations) should be extended to consider the recruitment, experience and advancement of different groups of women and men, for example people of different ethnicities and class and those who enter science by non-traditional routes. Research of this type should remain alert to the needs of policy makers since a dilution of groups' identity can produce findings which are too multifarious to act on.

More empirical research is needed to study the ways in which organisations and individuals use the claim of 'objectivity' in scientific education and research (knowingly and unwittingly) to reinforce gendered stereotypes, gendered sub-texts in organisations, and gender bias in the assessment and reward of excellence. Examples could be compiled of good practice to demonstrate how scientific research can be carried out so that the topic and the researcher's standpoint are reflexively considered in an emancipatory context. Clarification of which methods and ethical undertakings can be most appropriately applied from social science to science settings would be valuable.

5.8. Policies towards gender equality in science

Key Issues

There are a number of recent accounts which describe the development of policies and initiatives to address gender equality in science education and research (for an extensive review of UK initiatives see Phipps 2008, Rees 2001). This chapter does not intend to replicate this work but to assess the literature which reviews and evaluates the scope and impact of policies in this area and come to a judgement about its contribution and sufficiency.

In addition to policies which aim to promote gender equality in science, there are other policy areas which influence individuals' employment decisions. Many of these are implicit in the publications about this topic:

- *Employment relations acts*: to grant employees the right to take unpaid leave to deal with family emergencies and the right to request a more flexible pattern of work of meeting the needs of dependent children and adults as ways of improving retention and lowering absenteeism and stress in the workplace
- *Childcare and carers' strategies*: to increase the quality, provision, affordability and take-up of local childcare and health and social care provision to facilitate employment rates among women and men of working age.
- *Anti-segregation and pay initiatives*: to involve businesses and the public sector investigating and addressing pay differentials, and re-conceptualising part-time work so it is seen as a valid working pattern at all levels of an organisations.
- *Skills and workforce development commissions, reports and reviews :* To promote the acquisition of skills in new growth sectors, to encourage enterprise, to increase the skills of the prospective and current workforce.
- *Social inclusion policies*: to improve access of the poorest communities to ICT, delivering basic skills training in local venues, supporting social enterprises.
- *Anti-discrimination legislation*: to uphold the right of women and minority groups in the population to access employment opportunities, goods and services on equal terms.

Analysis of the GSD provides the following description of the literature on which this section is based.

Number and percentage of publications

	n	%
Ireland	119	38.9
United Kingdom	389	37.3
Anglo-Saxon CS	**392**	**37.1**
All Cs	**1,296**	**28.5**

Relation with other topics

	%
Horizontal segregation	54.8
Vertical segregation	52.8
Pay and funding	22.2
Stereotypes and identity	51.0
Science as a labour activity	37.5
Scientific excellence	19.1
Gender in research contents	37.2
Policies towards gender equality in research	100.0

Average number of publications per year

	Average
1980-1984	0.4
1985-1989	2.8
1990-1994	5.8
1995-1999	12.0
2000-2004	26.8
2005-2007	38.0
2008-2009	19.5

Methodological approach

Empirical research	**%**
Non empirical research	43.1
Empirical research. Quantitative techniques	11.2
Empirical research. Qualitative techniques	30.1
Empirical research. Quali-quantitative techniques	15.6
Total	100.0
Approach	**%**
Conceptual	38.5
State-of-the-art	42.6
Compilation of statistics	23.0
Building gender indicators	4.6
Empirical research. Quantitative techniques	26.8
Empirical research. Qualitative techniques	45.7

Empirical research techniques

Quantitative techniques	**%**
Representative sample	46.7
Micro-data	30.5
Longitudinal/cohort	10.5
Multivariate analysis	42.9
Qualitative techniques	**%**
Biographical research	8.4
Case studies	27.9
Content analysis	10.6
Interviews	65.4
Observations	21.8

Research Questions

- How can policy be used to incorporate a gender perspective into science teaching and research activity?
- How has gender and science policy developed over time? Can criteria for success be identified?
- What types of projects and programmes have been developed to address gender differences?

Research Approaches

Accounts of the development of equality legislation in the UK and Ireland have positioned these developments in the context of the ***European Commission's leadership*** in this area, most of the literature considers equality in policy making as a whole, rather than in the sphere of science specifically. For example Rees (2001) has presented strong cases for the importance of EU directives, National Action Planning processes and constitutional treaties such as the Lisbon Treaty in compelling governments to address the issue of equality as a top level priority. As described in the introduction, the adoption of equality commitments and the legislation which enshrines them has been shaped by the national context and degree of political will. It varies in the UK and Ireland in terms of its scope and reach.

Research on the policies to improve the gender balance in science has tended to be comparative, across all member states, and interested in learning from the most well developed legislative systems to inform the practice of new members. Relationships between the proportions of women employed in research and gross national investment in R&D, female economic activity rates and the nature of social welfare support have been examined. In these analyses the UK and Ireland come out favourably positioned among groups of countries which are leading the way or are pursuing innovation. Both have been identified as becoming more proactive in the promoting gender equality in scientific research areas in terms of legislative commitments to gender mainstreaming and the introduction of top-down structural initiatives.

The sizable body of UK literature on ***national policy*** has produced an analysis of the political and ideological positions which have informed its development, recognising two drivers: first social justice; lobbied and campaigned for my social movements and their political allies, and second economic growth supported by business and government to secure untapped (female) talent and in doing so to level the playing field. The 'business case' for increasing the number of women in the science industries has a number of different strands: first it draws on human capital theory to argue that by not making use of all the available trained resources, employers are narrowing the pool of talent they can choose from. Underutilising a section of the labour market is ineffective especially at times of skills shortages. Underutilisation may extend to failing to maximise the potential of women already employed in the sector albeit in lower skilled occupations and roles where they are not working at their proven ability nor have an opportunity to do so. Growth and productivity both suffer in this case. Finally it is easier to identify and to meet customer demands and expectations if the people creating and delivering the products goods or services are as diverse as they are. The central feminist challenge to equality delivered through market structures is that they individualise the barriers which women face, rather than addressing women's historical disadvantage. As women make up half the population, not a minority group, it is argued that policies should aim to achieve social justice by redistributing resources and rewards not only increase women's ability to access them. In practice polices express a mix of the two perspectives, indeed many feminists are prepared to use all available agendas and bend them to social justice ends in order to secure change now in women's daily lives.

Literature on the national policy framework has not been accompanied by consideration of regional policy contexts in the UK or Ireland despite the allocation of resources for enterprise and economic regeneration based on new technological industries being delivered by regional structures. By far the largest body of literature on policy development has been focused at the

institutional level and in particular Higher Education Institutions. This is perhaps not surprising given that Universities and Colleges are at the frontline of implementing policy intentions to increase the number and status of women scientists and have developed local strategies and approaches to both comply with and go beyond sector and national requirements. Although this research is often focused on only one institution there are opportunities and supportive infrastructure (such as the High Education Funding Councils, the Associations of Vice Chancellors etc) for successful policies to be transferred and scaled up, although these links are not considered in depth.

A popular way of researching policies has been to focus on ***process*** (also referred to as 'policy transfer'). This is summarised in the diagram below. It describes a number of distinct stages; from the inception of policy goals, underpinned by political ideology and gender theory, to the development of delivery mechanisms or instruments which assign roles to different actors and establish entitlements and the allocation of resources. These instruments may then come to be trialled in special projects and programmes to demonstrate their effectiveness or worthiness, or gain credibility and muscle through being enshrined in legislation. The policy process does not occur in a vacuum and so consideration of past history, the political climate and the competency and maturity of existing administrative structures are also elements in the mix. Finally evaluation may have been commissioned to examine the outcomes or impact of the programmes put in place. The role of different actors and institutions in driving, influencing and limiting the progress of policy development are also considered. They include consideration of the roles played by the women's movement and grass roots women, professional organisations particular governments and champions, leading scientists who are 'critical friends' and appointed officers of the state.

Figure 32: Dimensions of the Policy Process

<table>
<tr><td rowspan="3">Constrained / enabled by past history and readiness of institutions and state infrastructure</td><td>(1)
Setting policy gaols / objectives</td><td>(2)
Development of appropriate policy instruments</td><td>(3)
Enactment through legislation / special programmes</td><td>(4)
Evaluation of policy impacts and outcomes</td></tr>
<tr><td colspan="2">Informed by political ideology / gender theory</td><td>Mediated and facilitated by actors</td><td></td></tr>
<tr><td colspan="4">Evaluation provides feedback loop</td></tr>
</table>

A number of academics have chosen to look retrospectively at the policy process to identify which elements in the process have made a difference to the reception and sustainability of policy delivery through programme or projects. Some of these aim to identify criteria for success which are readily transferable between projects and disciplines within the board spectrum of science and technology. There a large group of studies which record and describe the design and implementation of specialist programmes targeted at women. However, very few of these accounts focus on evaluating outcomes, particularly using quantitative measures, although some have collected qualitative data from participants to illustrate the impact of particular programmes or projects on individual women's lives. Recent large scale investments in promotional infrastructure for gender and science has led commentators to predict that the evaluation stage of the progress will grow in significance. Analysis of the GSD shows that evaluation is missing, or is very limited in its remit, or has only looked at a superficial level in order to supply case studies or exemplars.

Research which has focused on the development of policy instruments can also be distinguished in the GSD, again this work is interested in the longevity of policy ideas, linked to their relationship with past and present theories of equality. There are a number of accepted typologies describing policy instruments, compiled in the spirit of informing practice more widely.

These include:

- Equal treatment law (bottom up, supporting individuals)
- Gender mainstreaming (top down, changing institutions, hierarchies and gatekeepers)
- Positive action (bottom up, and top down)
- Sex disaggregated statistics (provision of sources of evidence)
- Dedicated equality practitioners and departments (sources of knowledge)

Findings

The Anglo Saxon publications give a thorough analysis of the ideological underpinning of the development of different gender equality policies demonstrating their limitations and also the range of political arguments which have been employed by feminists, governments, business to advance the agenda (Arends and Volman 1992),. Fewer publications focus solely on policies for gender equality in science. These make the following type of contributions:

- Devine (1992) argues that the 'liberal' feminist strategy of upholding equality of opportunity for young women to enter and qualify in engineering has not substantially reduced segregation in technical professionals since it does not tackle men's historic domination of working practices through the redistribution of resources or positions.
- Henwood (2000) outlines the critique of liberal approaches to gender segregation in computing and IT education which expose their assumptions about the neutrality of technology and therefore the built in failure of programmes designed to increase women's access to that technology. In her view, the alternative interventions proposed are also unsatisfactory since they either deal with women's diverse relationships to technology producing many piecemeal actions, or universalise women's experience of technology producing initiatives which are themselves exclusive. She argues for the development of a critical and constructionist approach in educational programmes.
- Rhysjones et al (1980) reviewed the work of the Construction Industry Board in the UK to implement equal opportunities for women in the industry at both professional and operative levels. The authors argue that the work should be contextualised in a business case for diversification of the construction workforce since they would give it greatest credence in the changing economic conditions and employment market (of 1980s).
- Murray (2002) Examined the review of women dentists in the National Health Service (NHS) carried out by Dame Margaret Steward, published 2001. She identifies that this review was motivated by business case issues related to future workforce planning rather than concerns about equality per see. Issues included women becoming the majority of undergraduates, a majority of qualified female dentists working part-time hours, the clustering of women at associate level in general dental practice or in the Community Dental Service, and the low return rate of women to dentistry following a career break.
- Evans et al 2007 Assessed the robustness of the business case for increasing the proportion of women employed in the Information Technology Electronics and Computing industry and report on exampled of companies who have adopted this ideological position and following it though in practice.

Overlapping with findings on Science as a Labour Activity there are a group of publications which look at the implementation of equal opportunities policies within the Higher Education sector. These examine policies at institutional level and provide full descriptive empirical accounts of ingrained structures and cultural practices which act as barriers to their effective operation; these aspects include: promotion systems reliant on publication track records, professional autonomy, an isolationist culture, poor human resource management functions, work load intensification and a lack of organisational understanding or commitment to equality (Cole 1998, Forster 2001, Bagilhole 2002, Bagilhole and Goode 2002, Doherty and Manfredi 2006, Deem and Morley 2006, Rich 1999).

The last section of publications are concerned with the policy process; the instruments, projects or programmes designed to support women. A few publications take a comparative or retrospective view reflecting on a number of different instruments / projects in order to identify

criteria for success and the scope for replication and up-scaling (Acker 1992, Pirrie et al 2002). The majority describe localised single programmes and the impact which participants report they have had on their careers. Again not all these publications focus only on science disciplines (for example Heilmann and Sharp 1997 reflect on feminist student conferences). Studies that do examine science policy look at the following areas:

- Freeman 2003 compares UK approach to gifted girls to that of the USA,
- Herman and Kirkup 2008 on the use of ePortfolios to support women returners,
- Ordidge 1997 considers the use of media coverage, Mavin and Bryans 2002 on women networking for change.

There has been very little evaluation research focusing on the policies and programmes put in place in the UK and Ireland to achieve greater gender equality in scientific research. This may be because the resources committed to these programmes has been relatively small. Another reason is that until very recently programmes have been very local, based at single institutions or pilot initiatives and therefore of a temporary nature. There is no account of the impact that different decades of policies have achieved in quantitative terms, although there are many personal case studies of participating women's experiences and career trajectories.

Gaps

As highlighted under other topics, the lack of evaluation of publicly funded programmes which aim to tackle horizontal and vertical segregation in science means that lessons are not being learnt. A national synthesis of interventions by activity type (mentoring programmes, taster visits etc.) to compare level of resources, objectives, target audience and outcomes would also be useful as a way of sharing examples of effective practice. This synthesis could include related policy documents, and if undertaken at regular interviews and archived could become a permanent national resource.

6. Conclusions and recommendations for addressing gaps in research

Based on the literature gathered together in the Gender and Science Database this report has reviewed the topics which have concerned academics and policy makers over the last three decades. The great majority of the work has been focused on the UK experience, primarily because the science workforce has been a much more significant part of the UK economy for a longer time period than in Ireland. As discussed in the introduction, Ireland's science sector languished during the exodus of labour from the country following the second world war and only began to make its impact felt on its employment and education systems in the late 1980s due to American and European investment. From an academic standpoint this makes Ireland a very interesting case study; its equality policy and political commitment are very advanced in support of gender balance, facing an industry which is growing, young and possibly more receptive to gender initiatives than that of the UK.

The political debates about how to increase the size and skills level of the science labour pool has been waged in both the UK and Ireland: Politicians on both sides have been explicit in expressing the importance they place on scientific and technological advances for economic success in the global marketplace. Academics, equality campaigners and the women's movement have championed the contribution which women can, and should, make to the sector. These debates started in the UK in the 1960s and gained definition in the 1980s onwards, explained in this report in terms of three phases or positions. Ireland has benefited from its later start, adopting tried and tested policy initiatives. Its political debate has matured swiftly to reflect all three positions and in particular the most recent position bolstered by the political priority given to gender mainstreaming. In conceptualising the three positions in the political debate, this report has drawn on the typologies presented by two key papers (Cronin and Roger 1999, Glover 2001). Each position accords with one of the three decades covered. In the discussion of the topics which follow, the literature of the GSD has been organised, where possible, into positions, with the caveat that the categorisation of individual research studies can be indicative at best.

The recognition of the centrality of science for national economic prosperity alongside the observation that entry into science occupations was falling, is captured by Position 1. The reasons given for low scientific recruitment were based on theories of socialisation; that young women and men were put off science by popular and deep seated ideas about science as a 'dirty', non-creative industry in which only men traditionally worked. Teachers, parents and peers views contributed to form very certain notions of the types of jobs which were suitable for women and men of different classes of society. The policy initiatives which were developed to overcome these 'barriers', propose activities to enthuse girls and challenge these stereotypes. Position 2 emerging in the 1990s reflected a critique of Position 1: that it was not enough to ask girls to change their perceptions and to 'fit in' to science, the nature of how science was taught and how jobs were organised also needed to be changed. Pressure from the European Union on member states to reform their equality legislation in order to 'level the playing field' in their labour markets also influenced the debate. Position 2 represents an awareness that women's needs and 'condition' have to be addressed, in particular their rights to maternity leave, high quality childcare and an equal opportunity to progress in the science workplace alongside men, free from harassment or sex discrimination. Relevant initiatives broaden their scope from individuals to organisational procedures, the practices of managers and the mechanisms for support which organisations provide to women. Academics of sociology and social theory were amongst the first to decry these attempts as not enough. The 'equal treatment' perspective was criticised for leaving existing norms unquestioned and once again expecting women to make up any 'shortfall'. They challenged the assumption that women's absence and exit from science could be explained by a preference to prioritise motherhood. Position 3 identifies a gender bias in science, not only the practices of organisations which reflect the lifestyles and protect the interest of male workers, but also the epistemology and ontology it presents as the neutral. The policy response is only just beginning. Perhaps unsurprisingly, it has focused on higher education organisations where the contention first arose. It has gained credibility and support

from the European Union's campaign for gender mainstreaming. An approach to equality which aims to transform gender relations by systematically bringing bias into conscious view.

As we enter our fourth decade of political debate in gender and science all three positions are still current and useful. Additional resources and targeted legislation are needed to assist women to fully participate in the labour market, whilst challenging the perception that science is men's work; making science as a discipline and a workplace more gender neutral, ultimately benefiting all who work there.

Horizontal and vertical segregation are the main theoretical concepts which have been used to explain women's absence and exclusion from the scientific workforce. The literature of the GSD can be organised under these two headings, although papers tend to relate to one type of segregation or the other. Sex-role stereotypes and identity formation have been a key part of the explanation of why women choose not to study for science qualifications or pursue science careers (horizontal segregation). The gendered nature of science epistemology, ontology and pedagogy is being developed as another strand to explain women's reticence. Vertical segregation describing the barriers women face to advance through the scientific hierarchy to senior academic posts, industry executive jobs and committee appointments has many strands. Stereotypes are one part, along with an interest in labour activity (the length of the scientific day, expectations of post holders, organisational procedures, managers' interpretation and implementation of policies) and also the broad public policy context.

The design of research into segregation has been shaped by the nature of these concepts. In both cases, longitudinal data is vital to track changes over time, although educational attainment labour market entry and occupational position can more easily been interrogated due to the collection of national statistics. Progression with in organisations is dependent on institutional collection of data which is often incomparable across institutions. Efforts to centrally coordinate and require organisations to make public the gender breakdown of their pay and seniority systems have only recently been attempted under new legislation for gender mainstreaming. In the UK this attempt has been limited to public sector. Gaining an insight into women's and men's motivations, preferences and career decisions relies on talking or surveying them individually. The costs and time requirements of these studies necessarily limit their scope. The data that exists is very often institutionally bound, containing small samples of participants. Finding mechanisms to share and synthesise the existing data is of great importance as a first step to improving our understanding the degree of gender segregation.

The topics reviewed in the report reflect the political debate and have gone into more detail to describe the questions posed by the literature and the findings put forward. The opportunities and ideas which this literature has suggested for further research and the questions which have not yet been adequately answered are summarised below. They represent the views of the authors and are not intended to be exhaustive.

Approaches to research

1) In all topic areas a more robust approach to the collection of statistical data is required, with the following features:

- a national approach
- mandatory data collection for all funded interventions
- data collected by science disciplines, occupations and organisational types
- collect comparable data over time, through the consistent use of indicators
- synthesise existing national data to better effect

2) Whilst there has been prolonged and targeted funding in the UK to tackle gender segregation in science there is very little evaluation of what has worked and why. This is a significant weakness as lessons are failing to be learnt and opportunities to share good practice are being lost. The following research is needed:

- evaluation of all publicly funded interventions
- synthesis of existing information about interventions to compare level of resource, objective, target audience and outcomes

- evaluation of relevant policies at national and organisational level
- evaluation of the ways in which science organisations and companies have responded to new legislation (e.g. flexible working and gender mainstreaming)

3) The report has identified two areas where examples of good practice could be compiled:
- Examples to demonstrate how scientific research can be carried out so that the topic and the researcher's standpoint are reflexively considered in an emancipatory context. Clarification of which methods and ethical undertakings can be most appropriately applied from social science to science settings would be valuable.
- Whilst there is a growing body of literature about gendered pedagogy, a systematic examination of gender-aware teaching practices both in terms of subject content and single-sex classrooms is needed to identify why and how this can further benefit girls and boys. Evaluation of the potential of a gender mainstreaming policy to counter negative hegemonic discourses (Connell 1987) could be part of this work.

4) As part of efforts to raise awareness of gender bias in the practice of science, documentary analysis of women's past achievements in science should be continued to produce a more accurate and enriched account of historic scientific development. This could include women in the scientific teaching profession as well as in research.

Missing subjects

5) The majority of work on segregation in science has been carried out by academics, studying public institutions (schools and universities). Very little research has examined the experiences of women and men working in private sector organisations, in all the aspects discussed in this report.

6) The experience and career development of women and men working in manual trades and as self employed individuals is largely absent from the literature, as are the trajectories of those who enter the science professions via these routes.

7) A reseach focus on men in SET is absent from the literature, except in a minority of publications discussing boys' under achievement in schools. Applying Connell's concept of hegemonic masculinity (Connell 1987) to science disciplines could reveal very contractory experinces of advancement and barriers, giving an insight into which men succeed and why. The choices which men make and the ways in which masculine cultures are changing or can be changed should be an area for ongoing research.

8) Research which has addressed 'diversity' in science (education and occupations) should be extended to consider the educational outcomes, recruitment and advancement of different groups of women and men. This focus could include an exploration of the ways in which gender appropriate stereotypes vary for people of different ages, ethnicities and socio-economic group.

Horizontal segregation

9) **Young people's career choices** are relatively under-researched. In particular, findings suggesting that there is a lag between popular notions of scientific workplaces and their contemporary reality should be pursued to establish the level of understanding among pupils, parents, careers advisors and teachers about the range, content and remuneration of science occupations.

10) Attempts to enthuse girls require a closer examination of the interplay between individuals' **pleasure in science** gained though interests, experiences and performances and their attitudes to science. Research could include girls and boys at school, and women and men studying at university.

Vertical segregation

In all the following areas, a focus on individual science disciplines and a comparison between them is absent in the current literature and would be valuable.

11) It would be advantageous to know how the women (and men) who reach senior positions differ from those with flatter trajectories. This would require the collection of quantitative data identifying the **biographical characteristics** of senior SET women and men.

12) Studies in other contexts have shown that a significant percentage of women are working below their **proven potential** because of the lack of part time working at senior levels (Grant et al 2006). This issue has not been explored in science occupations. Quantitative research should be undertaken alongside qualitative studies of employers' assumptions underlying the construction of senior jobs.

13) Research on the **'ideal' SET worker** should be extended beyond the current examination of higher education managerial practices in normalising a highly competitive role model focused on producing quantifiable academic outputs (and therefore more suited to male career paths) (Bagilhole and Goode 2002). Within this work, women's alternative contributions to workplaces (for example their pastoral and administrative roles) should be recorded and their value debated.

14) **Women's awareness** of a gendered bias and hence their decisions about where and how best to deploy their effort for maximum return has not been sufficiently studied as part of the 'pipeline' model. These studies should include both gender-aware women and their more 'traditional' female counterparts.

15) There are further opportunities to challenge and amend the assumptions made about '**women's preferences**' as part of the pipeline model. As in other sector studies, research should be undertaken to establish the lengths women go to, to maintain their commitment to paid employment, by balancing work and family life: do they readily exit when becoming mothers? There is some evidence that women have clustered into occupations and onto career paths which allow them greatest flexibility. The features of these 'feminised' enclaves could inform the design of jobs and environments in male dominated areas to make them more attractive.

16) Theoretical and empirical research is needed to elucidate further the ways in which **binary dualisms** expressed through stereotypes, operate in different science disciplines. The insights provided by Faulkner (2000) and others in the field of Engineering could be replicated in other subjects.

Resources

17) The research on the **gender pay gap** in science occupations has not yet presented a complete picture of the size and degree of inequality by science discipline.

18) Whilst a comprehensive study of the gendered nature of **research funding allocations** has been undertaken by Millard and Ackers (2008), this report should be augmented with further empirical research to demonstrate the discriminatory nature of practices and cultures and the organisations which uphold them, in order to provide a focus for policy intervention. Routine regular collection of statistics disaggregated by sex, at institutional and national level, about funding awards, prizes and fellowships should be made publicly available on an annual basis.

19) Longitudinal research is needed to establish the culminative effect of **gender bias in the system of assessing excellence** over an individual's life time. To identify at which points harm to a person's career trajectory is most likely to occur in science disciplines, again this work can be related to the 'pipeline' model.

7. Appendix

Subjects referred to in the commonly used abbreviations for science – SET and STEM

STEM subject classification

Subjects allied to Medicine

- Anatomy, Physiology & 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

- 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

Source: UK Resource Centre for Women in Science, Engineering and Technology, http://www.ukrc4setwomen.org/

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