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# Women in Science, Engineering and Technology: A Review of The Issues

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## Abstract

*Concern continues to be expressed over women's difficulties in advancing their careers as academic scientists. Though some sciences may be numerically 'feminised', few women reach the upper echelons of science. Scant attention has been paid to issues of the progression of women from non-traditional backgrounds, such as those from ethnic minorities, who may be particularly disadvantaged. What research there is indicates a variation between the sciences in terms of women's careers and patterns that are replicated globally. Explanations are now focusing on how the scientific culture itself acts as a barrier to women rather than on the notion that women themselves lack the requisite skills. The Athena Project is a policy response to this issue. Future research and policy needs to look more closely at differences between the sciences, how women from diverse backgrounds experience the academic labour market and epistemological connections between employment and engagement with the scientific agenda.*

## Academic women in science: is there a problem?

Despite a plethora of initiatives mounted in the last decade to address women's under-representation in both scientific and higher education employment, women appear to face considerable difficulties when advancing a career in academic science. The increase in the number of women graduates, including those from ethnic minorities, has not been accompanied by a concomitant increase in the proportions of women in academic posts, particularly in the science, engineering and technology (SET) disciplines – 'SET' being a UK term that refers primarily to the biosciences, physical and chemical sciences, mathematics and engineering. This is starkly revealed in quantitative data that show women occupying two per cent or less of professorial posts in many of the SET sub-disciplines (Bebbington, 2001).

For ethnic minority women, accessing higher education may be of greater concern than advancement in an academic career. Mirza (1995) states that, while white women academics are primarily concerned with problems of culture and management, the issue for black women is one of a struggle for access. At the same time, they, along with people from other ethnic minority groups, are over-represented on higher education courses in terms of their proportion of the general population and this is increasing (Connor et al., 1996). In terms of representation in SET careers, there are clear ethnic variations. Concern is currently being expressed over the under-representation of African-Caribbean people in scientific employment, as highlighted by the 'RESPECT' initiative. This trend starts from GCSE level and works through to higher education, so that African-Caribbean students are under-represented as science students compared to their numbers in the general population. At the same time, there is over-representation of Indian, Bangladeshi and Chinese students on science undergraduate courses (Baker, 2002). The literature on women in SET does not appear to highlight how women's experiences of scientific careers vary according to their individual differences, including their ethnicity or class backgrounds. It is important to bear this in mind in considering the research and policy developments that will be described in this paper.

Bagilhole (2000) highlights the well-documented, persistent phenomenon of women's under-representation in academic employment as a whole. Universities in Britain have been described as male bastions of privilege and power, and women's chances of entry, promotion and retention are generally lower than men's (Hansard Society Commission Report, 1990). Women are disadvantaged compared to men in terms of pay (Association of University Teachers, 1995), are more likely to be employed on short-term contracts and are less likely to apply for research grants even though they are as successful as men when they do apply (Blake and La Valle, 2000). Morley (2000) argues that it is in everyday practices such as bullying, stalling, sabotage, manipulation and spite that gendered power relations in academia are maintained. Such occurrences may appear trivial, subtle and difficult to capture, but at the same time they reveal the ways in which competition and domination are played out. According to Morley, the study of micropolitics within the academy can illuminate ways in which organizational power accrues.

The global nature of women's under-representation in academia is increasingly being recognised. Even in countries that are considered to be at the forefront of promoting gender equality, such as Finland,

women still encounter subtle forms of discrimination (Husu, 2001). Furthermore, high levels of political will, childcare provision and so on do not necessarily correlate with better career prospects for academic women (Husu, 2002). Women may also experience the academic labour market in profoundly different ways from each other, including those with disabilities and from ethnic minorities. A major concern is the lack of data. Essed (1999), for example, highlights the very real issue of the absence of ethnicity data in most European countries, so that ethnic monitoring is rarely carried out.

Data for academic staff disaggregated by gender show patterns of both vertical and horizontal segregation. The pattern of attrition (the further one goes up the hierarchy, the fewer the women) persists in all disciplines including business, social studies and language-based studies (Higher Education Statistics Agency, 2000). There are, nevertheless, disciplinary differences, with women best represented in language-based studies at almost every grade and worst represented in engineering and technology (see Table 1). When data for the SET disciplines by grade and cost centre (including all fields of SET except computer software) are examined, the stark under-representation of women becomes even more evident. In 1997–98 women represented 2 per cent or less of professors in many SET disciplines. Of 145 civil engineering professors, not one was female. The biosciences are rather better, but even here marked attrition is notable. While more women than men are now gaining PhDs in the biosciences (Bebbington, 2001) they still represent only 9 per cent of professors. Glover (2002) makes the point that, although some sciences may be numerically feminised, particularly biology, these are not necessarily the sciences where women get to the top. Glover argues that women's progress in scientific employment must be considered in terms of four distinct phases – qualifying, translating scientific qualifications into scientific employment, persistence and advancement. Engineering provides a particularly strong contrast with biology; here women are still heavily under-represented at undergraduate level as well as within engineering employment (see www.set4women.gov.uk, statistics channel, Table 24). Thus women's quantitative representation is clearly different from men's at every stage of an engineering career.

In considering disciplinary variations across European member states, a report by the European Technology Assessment Network (ETAN) on women and science (European Commission, 2000) shows a trend replicated across Europe of a generally higher representation of women in the social and biological sciences and a lower presence in the natural sciences and engineering, even though the percentages may vary

*TABLE 1*
Women as a percentage of full-time academic staff, 1998/99

| | | % women |
|---|---|---|
| Biology, mathematical and physical sciences | Professors | 4 |
| | Senior lecturers/researchers | 11 |
| | Lecturers | 21 |
| | Researchers | 32 |
| | Other grades | 22 |
| Engineering and Technology | Professors | 3 |
| | Senior lecturers/researchers | 6 |
| | Lecturers | 13 |
| | Researchers | 16 |
| | Other grades | 11 |
| Administrative, business and social studies | Professors | 12 |
| | Senior lecturers/researchers | 23 |
| | Lecturers | 36 |
| | Researchers | 47 |
| | Other grades | 33 |
| Language based studies | Professors | 18 |
| | Senior lecturers/researchers | 30 |
| | Lecturers | 49 |
| | Researchers | 46 |
| | Other grades | 65 |

*Source:* Table 16, Higher Education Statistics Agency 2000

somewhat between countries. Women's under-representation in mathematics, physics and engineering compared with higher proportions in the humanities and social sciences has been highlighted by Ackers (2001). Ackers also draws attention to the point that, even in disciplines with high numerical feminisation, vertical segregation may be considerable.

The pattern of steep attrition is replicated in the USA; evidence here shows that high levels of 'getting in' (quantitative feminisation) may not lead to women scientists 'getting on' (vertical feminisation) (Glover, 2000). In the biological sciences, US women's career trajectories show similar patterns; whilst they make up a considerable proportion of post-doctoral and other academic positions (approximately 40 per cent in 1995), they still hold a smaller proportion than men of tenured positions, though these have shown a steady increase since the mid-1970s.

The period 1973–1995 has similarly seen an increase in the number of female assistant and full professors (Greenwood, 2000).

## Why the problem?

The 'domestic responsibilities model' is a much posited explanation for gendered patterns of occupational segregation in the labour market, though research has questioned the notion that women's labour market disadvantage can be read off primarily on account of the demands of motherhood and the family (see, for example, Bebbington, 2000).

Morley (2002) questions the appropriateness of this model as an explanatory framework. She argues that the model positions women in normed relationships in terms of the family, implying that all women share a commonality of life-style, that unmarried or childfree women do not have responsibilities in the private sphere, and that women have restricted mobility and are in fixed situations from which they cannot easily escape.

Recent research involving reanalysis of UK census data from 1971 and 1991 (Blackwell, 2002) finds distinctive career patterns of family formation amongst SET graduates. The study confirms anecdotal evidence that women in SET occupations have difficulty in reconciling the competing demands of professional and family life, and that these conflicts are particularly marked for women in the traditionally male-dominated occupations. Blackwell's analysis shows that women in science and technology occupations tend to have children later in life than those in other occupations. They are also more likely not to have children at all. She suggests such family formation patterns may reflect the institutional contexts in which women with SET qualifications study and work. The study appears to lend support to the idea that there is a relationship between the gender balance of an occupation and the level of tolerance and provision of flexible working practices afforded to women with children. Nevertheless, it is important to point out here that women managers and even lower level staff within female-dominated occupations may themselves show a lack of tolerance and negative attitudes towards flexible working practices. Bebbington (2000) describes an instance in which a therapy manager was considered less competent to carry out her managerial role by the female staff she managed because she was a part-timer.

These apparently opposing perspectives beg the question as to what extent career paths are influenced by persistent cultural attitudes and expectations, which are based on pervasive social stereotypes, and the

level to which motherhood per se is experienced as a career obstacle. Husu (2001) in her qualitative study of academic women in Finland, noted that problems raised by her interviewees focused primarily on 'prevalent attitudes, prejudices, practices, organisational responses and regulations concerning motherhood in the scientific community' (p. 290). The reconciliation of work and family life was actively managed by Husu's respondents and there was a view that such skills were useful in the environment of paid work. Neither does the domestic responsibilities explanation explain why far fewer women take up physics and engineering in the first place. It could be said that women perceive these fields to be 'woman-unfriendly' for not easily 'fitting around' the family. However, this has not discouraged women from choosing medicine as a career; in spite of the long hours culture, women have been entering that profession in equal proportions to men for some time.

Much research has considered the ways in which gender discrimination is embedded within organisational practices themselves. Using empirical data from interviews with women academics, Bagilhole and Woodward (1995) show that sexual harassment is an under-recognised and underestimated phenomenon in the UK academic profession and a strong indicator that the problem lies with the academic culture. Their research adds weight to the argument that it is not that women are in deficit by lacking confidence, the ability to do science and so on:

> We must stop looking for possible deficiencies or deficits in women themselves and see it as a problem for universities, placed fully and squarely on their shoulders. It is important to recognise the crucial part played by sexual harassment in excluding women from full participation and success in the academic profession. (p. 50)

In her study involving British, Swedish and Greek women, Morley (1999) observes that, 'in spite of location in different logics, political frameworks and economies, voices chorused similar concerns about the prolonged subordination of women in the academy' (pp. 185–186). While she is cautious about over-generalising the findings of a study with forty informants, Morley suggests that employment disadvantage affects women in many places; but, importantly, she argues that employment issues are highly linked to epistemology, with discrimination against women perpetuating and upholding the male perspective in academia.

Little attempt has been made to explore epistemological links between women's disadvantaged position in academic science and the production of scientific knowledge itself. This is in spite of postmodern critiques of science that have included feminist challenges regarding the

ways in which scientific knowledge may be gendered. Feminists have argued that science is integral not only to systems of late capitalist domination but also to patriarchy (Rose, 1994). This critique has focused on unravelling the nature of sexism within science, including the gendering of scientific knowledge, the biologism of science in 'accounting' for female behaviour and the exclusion of women from scientific activity. Fox Keller (1985) based her thesis on the commonly held belief in which 'objectivity, reason and mind are cast as male, and subjectivity, feeling and nature as female' (p. 7).

Yet 'exclusion' may be an inappropriate term; the difficulties for women in casting their work as 'scientific', even when their education and professional practice are based on scientific principles, have been highlighted by Bebbington (2000). Women's work in the sphere of health care, even when shown to be systematic, rigorous and effective, is rarely labelled 'science'. As Elston points out, sociologists of science have been slow to recognise that nurses and paramedical professionals study and sometimes do science (p. 13). In consequence, this work is likely to forego the status and recognition that science may accrue.

However, it is not only in the female-dominated fields that women's contribution has been undervalued; women's work in the traditional, scientific, male-dominated fields has also been overlooked. The most obvious example of patriarchy and social closure is that of Rosalind Franklin. Franklin played a key role along with James Watson, Francis Crick and Maurice Wilkins in the discovery of DNA, yet Crick and Watson became highly successful academics while Franklin remained in obscurity until her death from cancer at the age of 37. Anne Sayre, her biographer, shows how Watson and Crick effectively stole Franklin's results, failing to acknowledge her contribution and ensuring she did not receive recognition (Sayre, 1975). Rose (1994) provides much biographical detail on the struggles of women scientists to gain recognition, pointing to the ways in which the scientific societies, including the Royal Society, have continued to exclude women from their fellowships. In the years 1901–1998 only 11 women have won the Nobel Prize in science out of a total 457 prizes conferred and only 16 women fellows of the Royal Society are living in the UK compared to 400 men (Meek, 2002).

A further perspective posited by social theorists of gender and science is the need to distinguish between the sciences. In attempting to explain women's position in science, Glover (2000) considers that the issue is 'not one of women in science in general, but rather one of women in the sciences' (p. 88).

The argument has been put forward that it is physics, not other sciences, that have remained obdurately male. This view is proposed extensively by Wertheim (1997), who emphasises interconnections between physics and Christianity, arguing that both exclude women in attempting to 'locate humanity in a wider cosmic sense' (Wertheim, 1997, quoted in Glover, 2000, p. 9). Wertheim suggests that both physics and Christianity have pursued theoretical explanations for creation in a way that alienates women.

To summarise, the question of why so few women reach the top in academic science appears to be most satisfactorily answered by focusing on the problematics of the work environment itself. There is resounding agreement in the literature of the need to move away from the 'deficit' model that finds women lacking, a position reiterated at a recent conference (Glover, 2002; Morley, 2002). The question of how and why different patterns of gender segregation exist among the sciences and how these link epistemologically to scientific endeavour requires deeper, more thoroughgoing exploration. Indeed, at a European conference last year, it was argued that what is needed is a more qualitative, epistemological approach to gender research (Braidotti, 2001).

## What has been done?

A number of significant policy developments on women in science took place in the 1990s in the UK and at European level. The 1993 Government White Paper *Realising our Potential* (HMSO, 1993) highlighted the importance of SET for the economic growth of the UK by stating that, 'women are the UK's single, most undervalued, and consequently underused human resource' (p. 57). A year later, the report resulting from the Rising Tide Committee was published (HMSO, 1994). The Committee was convened specifically to look at the issue of women's under-representation in science and to make recommendations as to how to rectify the situation. In the same year, the Commission on University Career Opportunity (CUCO) was set up by the Committee of Vice-Chancellors and Principals (CVCP), now Universities UK, to examine equal opportunities in higher education employment across the board.

The Athena Project was launched in 1999 and was given the specific task of improving the retention and advancement of women scientists in higher education employment. The project is funded until 2003 by the UK Funding Bodies and the Office of Science and Technology. The

most recent development has been the establishment in 2001 of the Higher Education Equality Challenge Unit (ECU), whose mission is to improve equal opportunities for employees in the UK higher education sector. Among the stated aims of the ECU are: to work with stakeholders in raising the awareness and profile of equal opportunities; to provide advice to institutions so as to help them secure improvements in equal opportunities; and to help specify appropriate data for supporting equal opportunities monitoring. The Athena Project is now part of the ECU and is developing its future agenda in tandem with this new, broader agenda. Athena is re-appraising its objectives in the light of legislation on ethnicity and disability, and pending legislation on diversity in employment that will look at religion, sexual orientation and age.

The Women and Science Sector within the Research Directorate General (DG) of the European Commission was established in January 1999. Last year, it was incorporated into the new Science and Society Directorate of the Research DG. In promoting women's participation in research, the Commission has been pursuing two objectives, the first being to stimulate discussion and the sharing of experience in this field among the Member States. The second objective is to:

> develop a coherent approach towards promoting women in research financed by the Union, with the aim of significantly increasing the number of women involved in research during the period of the Fifth Framework Programme. (European Commission, 1999, p. 4)

One of the Rising Tide's recommendations was the need to set up a dedicated unit within the Office of Science and Technology to promote science as a career for women. Established in 1995, the Promoting SET for Women Unit focuses on women and science across the life course, including trying to get more girls to take up science subjects and science careers. Of relevance to academic women is the unit's aim to promote SET as a fulfilling career, including in higher education. Its remit as regards women academics has included part-funding the Athena Project, commissioning research now completed on women returning to science (People, Science and Policy, 2002) and participating on the steering group of a study commissioned by the UK Research Councils and the Wellcome Trust on gender and grant application behaviour (Blake and La Valle, 2000).

Activities of the Athena Project have included the awarding of grants to 11 development projects that have been carried out in UK higher education institutions. In addition, several regionally-based, local academic women's networks (LAWNS) have been set up and a new initiative is the Athena Awards Scheme. In 2000 and 2001 Athena developed

a research strategy aimed at collating and disseminating research on women's careers in higher education, particularly within the sciences. Recent research findings were presented at the Athena research conference held last year at the Royal Institution of Great Britain (Bebbington, 2002).

The Women and Science section of the Research Directorate General has organised several high profile conferences (European Commission, 1998; European Commission, 2001), led the drive to develop better indicators on women in science and published the ETAN report (European Commission, 2000). The report considers, on the basis of evidence from across the Member States, how the role of women can be enhanced in science, engineering and technology policy and practice. The report is targeted at academia and industry, the EU and its institutions, the Member States, and women and men scientists. Its wide-ranging recommendations include: legislative change; developing, collecting and publishing gender disaggregated statistics; mainstreaming equality in the Fifth and Sixth Framework Programmes; and initiating positive action under the Sixth Framework Programme. It also recommends that Member States put in train initiatives to develop best practice in the recruitment and employment of scientists.

## Has policy been successful?

How has the situation changed as a result of policy developments? CUCO monitored progress across the whole of higher education employment in 1994, 1996 and 1998. These surveys showed an improvement in the promotion and implementation of equal opportunities in relation to higher education staff. However, in a survey of higher education institutions by Carter et al. (1999), it was found that a third did not have a racial equality policy and even when there was a policy certain areas of employment, such as career progress and contract status, were not covered.

Nevertheless, reports published in the late 1990s highlighted the continuing need for action: the Bett Report (Independent Review of Higher Education Pay and Conditions, 1999) and the Dearing Report (National Committee of Enquiry into Higher Education, 1997). They recommended equal opportunities for all staff via equal opportunities statements and pay and publication of explicit criteria for promotion. Thus, in spite of activity in the mid-90s, by the late 1990s there was still much to be done, as was shown by persistent gender segregation within academic employment and the clear need for a further initiative – the

ECU. The ECU is funded for five years. Given that it was established less than a year ago, it is early days to report on progress.

Athena's projects have reported benefits to individual institutions in terms of networking, developing mentoring schemes and generally raising awareness of issues of women's careers in scientific disciplines both at grass-roots level and with policy-makers (Bebbington and Fox, 2002). The long-term effects in terms of quantitative and qualitative change are more difficult to ascertain, partly due to the thorny problem of disentangling cause and effect. Athena is a project with limited funding and a limited lifespan. This paper has already highlighted the complex, historically-embedded nature of women's under-representation in science; the work Athena has sponsored constitutes a small, but significant, contribution to addressing this.

The Promoting SET for Women Unit is also an initiative with a limited timeframe; it is presently planned to continue until 2007. The Unit has made concerted efforts to monitor quantitative change by making publicly available statistics on women in SET on its website. The Unit plans to up-date these data year-on-year and to supplement this information with a written commentary highlighting notable statistical trends.

Much work has been undertaken at the European level to improve gender indicators in science. A first step involved mapping existing data to see what these revealed in terms of patterns of women's scientific employment across the EU (Glover and Bebbington, 2000). A recent outcome is the Eurostat publication 'Women in public research and higher education' (Laafia and Larson, 2001). In terms of other European actions, it is expected that most activity needs to be carried out at Member State level, with the EU acting as a catalyst and individual scientists lobbying for change (European Commission, 2000). The ETAN report is wide-ranging in its recommendations and it will be interesting to see how these are applied, how they will be evaluated and what the outcomes will be.

Athena is the first of these initiatives to re-evaluate its goals in the light of differences between women. The ACRISAT project (African-Caribbean Representation in Science and Technology) is drawing attention to the low numbers of African-Caribbean people in scientific careers, thereby highlighting ethnic divisions within the scientific labour market. Athena and the ECU have taken first steps in exploring this issue and to move beyond the widespread tendency to focus only on commonalities between women. This latter point has been underlined by Nkweto Simmonds (1992):

> If we continue to see difference in feminist theory as primarily concerned with gender differences we continue to limit the use we can make of difference as a tool for analyzing the realities of all women. Too much time and energy has been spent theorizing difference as negative and divisive, an impediment to universal sisterhood. (p.54)

This tendency to view women as a single, unified group with a common identity is reflected in statistical analyses of women in scientific employment whereby statistics disaggregated by ethnicity are rarely presented: a reason often given is that the numbers are 'too small'. Without monitoring systems, the problem cannot be quantified and tackled. This is a challenge ahead for Athena.

A further issue in terms of policy is the need to fully contextualise quantitative data on career progression; quantitative change in terms of more readers and more professors is in itself a limited indication of progress. Though quantitative data may be useful to policy, they may be misleading if divorced from broader issues, such as pay and conditions. Husu (2002) discusses the complexities around the varying proportions of women in the professoriate in the various European Member States. Turkey, for example, has a very high proportion of women professors – when compared to the rest of Europe, Australia, USA and Canada – at 21.5 per cent. Husu explains that Turkey has an elitist higher education system in which class rather than gender is the salient segregating feature in academic recruitment. Husu also makes the point that the proportions of women may increase alongside a decrease in the status of academic work. Siemienska (2000) describes Polish academic women as 'winners among the losers', showing how during the transition from socialism to capitalism, there has been a deterioration of the position of Polish universities with a concomitant worsening of working conditions. Indeed, Morley (2002) asks whether quantitative change is more a case of redistribution rather than recognition, that whatever less powerful people get access to immediately loses its value. She poses the questions, 'what is the actual change in composition? What impact is that actually having in terms of women's rights?' (p. 34).

Another point is that there are few examples of qualitative evaluations of policy, a notable exception being a description of what happened when a sexual harassment policy was implemented in the University of Oslo (Søyland et al., 2000). University staff members were required to sign a declaration confirming they had read the guidelines. Initially, there was an outcry, with headlines appearing in a national paper and some academics even threatening to resign in protest. Since then, the situation has calmed and the guidelines are proving useful.

This is one example of a close, descriptive account that highlights negative as well as positive reactions to policy implementation.

Thus, policy has had some successes, but there is widespread agreement that slow change has occurred, as far as equal opportunities are concerned, because of a failure to tackle institutional aspects of discrimination. Hearn (1999) argues that gender equality in universities needs to be addressed by 'reducing the quantity and improving the quality of men managers in universities' (p. 173). He suggests setting targets to bring about a better gender balance within university management and using managerial changes as opportunities to challenge men's practice of management by men and women. According to Morley (2000), policy interventions have regarded gender as a 'background variable rather than as a construct embedded in learning processes. Equality and social justice issues are reduced to those concerning access' (p. 20). Morley argues that feminist scholarship and major policy initiatives have not developed along the same trajectory, with policy being driven more by market forces than by social justice.

## Conclusion

The problem of women's under-representation in academic science requires clearer delineation, recognising that their career trajectories are likely to vary markedly between the scientific disciplines. Serious attention needs to be paid to the point that women experience the academic labour market in a variety of ways on account of their individual differences so that a holistic approach can be reached. To date this has largely been overlooked. This will require exploring the ways in which differences such as ethnicity, class and gender intersect. Reay (2000) and Hey (2001), for example, examine the gendered, classed nature of contract research work in higher education institutions. In this way inclusivity will be incorporated and mainstreamed into research and policy on women in academic science.

Another requirement is for a deeper examination of the links between women's participation in science and their engagement with scientific knowledge production. It has been said that we need to consider not only women in science, but also women and science (Glover, 2002). Sustained efforts rather than short-term fixes are required with explicit goals, implementation plans and quantitative and qualitative evaluations of processes as well as outcomes, bearing in mind that any initiatives are likely to falter along the way, given the complex processes involved in knowledge production. This agenda will become increasingly imperative

as worries increase over declining numbers of science graduates (Eggins, 2002) and the likelihood that historically under-represented groups will be targeted as potential sources of scientific labour. It will be essential to observe how and under what conditions this increased participation will take place.

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