



## Theorizing Progress: Women in Science, Engineering, and Technology in Higher Education

Title	Theorizing Progress: Women in Science, Engineering, and Technology in Higher Education
Author(s)	Cronin, Catherine
Publication Date	1999-08
Publisher	Wiley
Repository DOI	<a href="http://dx.doi.org/10.1002/[SICI]1098-2736(199908)36:6&lt;637::AID-TEA4&gt;3.0.CO;2-9">http://dx.doi.org/10.1002/[SICI]1098-2736(199908)36:6&lt;637::AID-TEA4&gt;3.0.CO;2-9</a>

# Theorizing Progress: Women in Science, Engineering, and Technology in Higher Education

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## Full reference

[Cronin, C. and Roger, A. \(1999\), Theorizing progress: Women in science, engineering, and technology in higher education. \*Journal of Research in Science Teaching\*, 36: 637–661.](#)

## Abstract

A conceptual framework of positions on women in Science, Engineering and Technology (SET) was developed, showing a chronological progression of the main approaches to women's underrepresentation in SET during the past 20 years. Numerous initiatives have been advocated to address women's underrepresentation in SET in higher education. This article arose out of one such initiative, Winning Women, which was intended to help higher education in Scotland move toward good practice in this field. Two members of the project team describe their key findings and experiences. They illustrate how the underrepresentation of women in SET continues to be both progressive and persistent (using a SET parity index). The conceptual framework was conceived and developed from a metaanalysis of feminist theories of the gendered politics of science and technology.

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Women are underrepresented in science, engineering and technology subjects in higher education.<sup>1</sup> Of the 31,205 undergraduates studying science, engineering and technology (SET) in Scottish higher education institutions in 1995–1996, women accounted for only 32%. This ranged from 14% in engineering and technology to 62% in biological sciences. These figures are roughly similar to those for the United Kingdom as a whole, and the underrepresentation of women in most SET subjects persists in many other European countries, the United States, Canada, and Australia (Ainley, 1990; Byrne, 1993; Frize, 1992; Matyas, 1992a; National Research Council [NRC], 1991). Since the early 1980s, efforts have been made to explain this. In the United Kingdom, national efforts have included the launch of Women in Science and Engineering (WISE) in 1984, the publication of the White Paper on Science and Technology, *Realising Our Potential* (Her Majesty's Stationery Office [HMSO], 1993) and *The Rising Tide* (HMSO, 1994), and the subsequent establishment of the Development Unit on Women in SET within the Office of Science and Technology.

In 1995, the Scottish Higher Education Funding Council (SHEFC) continued these efforts by launching a 2-year Women in Science, Engineering and Technology initiative, at a cost of £300,000, to research and document examples of good practice which could be implemented in Scottish higher education to increase the participation of women in SET. The Winning Women research project, on which this article is based, formed the first and third strands of this initiative.<sup>2</sup> The second strand was composed of a number of related action projects in several Scottish higher education institutions.<sup>3</sup>

The Winning Women research team was composed of seven researchers from backgrounds in science, engineering, women's studies and education in the Universities of Dundee and Stirling. An academic chemist led the team. Our specific remit was to search for and analyze a wide range of national and international research, and to produce guides to good practice in women's access to, participation in, and progression through courses and careers in SET in higher education. As two members of the Winning Women project team, we report in this article how the seemingly straightforward task of identifying examples of good practice revealed itself to be an exceedingly complex one. We attempted first to define good practice so that we could recognize it. We realized that it would be impossible to identify good practice across all SET disciplines, as each discipline (and each institution) requires particular solutions to meet their particular circumstances. Related to this, we decided to minimize the conflation of science, engineering and technology (inherent in the term SET) by highlighting, wherever possible, where specific statistics or issues varied considerably

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<sup>1</sup> For this project, four subject areas were considered as comprising "science, engineering and technology" subjects: biological sciences including biology and biochemistry; physical sciences including chemistry, physics and astronomy; mathematics and computing including computer science, mathematics and statistics; and engineering and technology including all types of engineering as well as metallurgy, polymers and textiles. These categories have been defined by the Higher Education Statistics Agency (HESA).

<sup>2</sup> The Scottish Higher Education Funding Council funds higher education in the 21 higher education institutions in Scotland. Of these, 14 institutions offer science, engineering and technology degrees. Winning Women in Science, Engineering and Technology in Higher Education in Scotland was a research project funded by the Scottish Higher Education Funding Council. The views expressed in this article are the authors' and not necessarily those of the Scottish Higher Education Funding Council.

<sup>3</sup> Concise reports of each of these projects are contained in the *Winning women guides*: Duffield, J., Cooper, M. & Roger, A. (1997). *Access guide: Women into science, engineering and technology in higher education*. Edinburgh: Scottish Higher Education Funding Council; Cronin, C., Cooper, M. & Roger, A. (1997). *Participation guide: Women in science, engineering and technology in higher education*. Edinburgh: Scottish Higher Education Funding Council; Higgins, C., Watt, S., Evans, R., Cooper, M. & Roger, A. (1997). *Progression guide: Women in science, engineering and technology in higher education*. Edinburgh: Scottish Higher Education Funding Council. The guides are also available on-line at: <http://www.shefc.ac.uk/shefc/publicat/others/wiset/guides.htm>

between SET subjects. However, we attempted a general definition of good practice which could be tailored as necessary. We proposed that initiatives demonstrating a clear understanding of the nature and causes of women's underrepresentation in science, engineering and technology, and effectiveness in bringing about improvement, could be said to embody good practice.

This definition led us to three stages of research. We decided first to establish by up-to-date research and quantitative analysis the exact nature of the underrepresentation of women in SET. Second, we sought to consider the various explanations of the underrepresentation of women, drawing upon research in the United Kingdom and further afield. Although not an explicit part of the remit, we also undertook to recognize the interrelated inequalities of gender, race, and class. Third, we sought to identify initiatives which addressed the recognized causes of women's underrepresentation and which contributed to increasing the representation of women in SET and improving the quality of their educational experiences. To assess the comparative effectiveness of these initiatives, we developed a conceptual framework that enabled us to assess them in terms of their assumptions about gender, science, and technology, i.e., which perceptions of the problem motivated them and which areas of activity they sought to influence.

During the course of the project, we benefited from much encouragement and support, but also encountered obstacles and resistance. In the first part of this article, we describe the main challenges encountered during the project, and in the second part we present the conceptual framework of positions on women in SET which we employed to explain some of these difficulties.

### **Encountering Obstacles and Resistance**

The first part of this article describes the major obstacles and forms of resistance which we encountered during the Winning Women project. These are presented as they arose during the three key stages of the project: defining the underrepresentation of women in science, engineering and technology; exploring the causes of women's underrepresentation; and surveying "women in SET" initiatives.

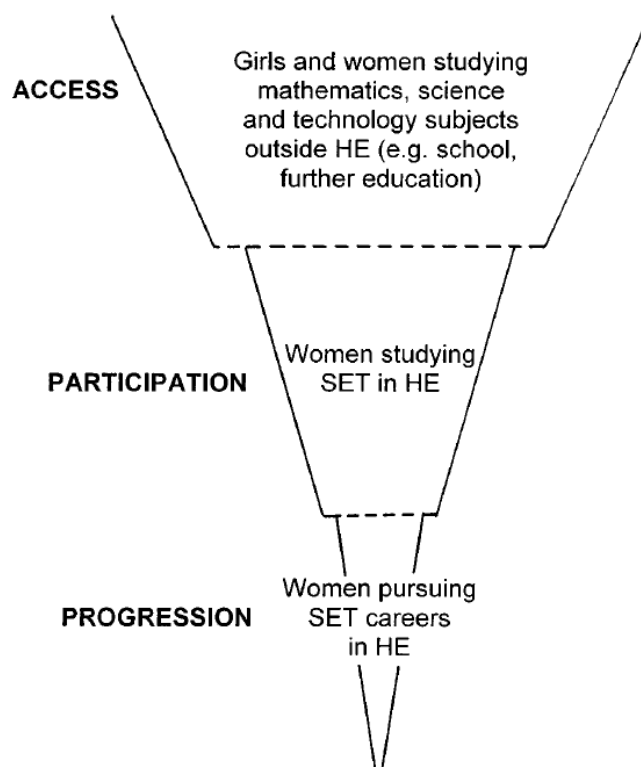
#### ***Defining the Underrepresentation of Women in Science, Engineering and Technology in Higher Education***

To define and characterize women's underrepresentation in science, engineering and technology, the project team gathered and summarized a large amount of quantitative data: for example, proportions of women entering, progressing through, and leaving specific SET disciplines, gender differences apparent in these patterns, and historical trends. We believe strongly that gathering, presenting and articulating this information are essential in establishing the rationale for concerted action to redress this underrepresentation. A commonly held belief, even within higher education, is that more women than ever are studying these subjects, so "what more needs to be done?" As noted in a 1993 Scottish report on women in engineering, as well as science and technology, is this widely held view that there are no longer any barriers (Scottish Wider Access Programme, 1993). Many higher education staff are of the opinion that considerably more females are now studying science, engineering and technology than in the past, and that female and male students are treated equally (Scottish Wider Access Programme, 1993; Thomas 1990).

Our analysis revealed, however, that the underrepresentation of women in SET is a continuing trend that is particularly marked in engineering, computing and physics. We described this underrepresentation as both *progressive* (worsening over the course of higher education) and *persistent* (over time), illustrated below: first by a funnel diagram, and second, by a SET parity index. These are described below.

*Progressive Underrepresentation of Women in SET.*

A funnel diagram (Figure 1) was used to illustrate the progressive underrepresentation of women between and within three stages: access (entering higher education to study SET), participation (studying undergraduate and postgraduate SET courses), and progression (pursuing academic careers in SET in higher education). The funnel metaphor is similar to the pipeline metaphor used widely in the United States to illustrate the progressive underrepresentation of women in SET (Matyas & Dix, 1992c; NRC, 1991).



*Figure 1.* Funnel diagram: diminishing representation of women in science, engineering, and technology in higher education.

This diagram shows that the total number of girls and women who are qualified to enter and who enter SET courses diminishes dramatically because they are filtered out at various stages. Of those who do complete SET courses, relatively few progress to postgraduate level or beyond, to lectureships and chairs. As shown in Table 1, this funnel effect is evident across all subjects in higher education, but is particularly extreme in SET subjects.

*Table 1.* Proportion of students/staff who are female, Scottish Higher Education Institutions, 1995–1996

Group	Proportion Female	
	SET subjects	All subjects
Undergraduate students	0.32	0.44
Postgraduate students	0.28	0.51
Lecturers	0.17	0.33
Senior lecturers	0.06	0.16
Professors	0.04	0.08

We sought to determine the critical points at which women leave SET, and where they go when they do leave. We encountered a major obstacle here, however. Much of the data required to describe fully women's (and men's) patterns of access, participation, and progression in SET are simply not collected in sufficient detail by most SET departments or higher education institutions (HEIs). As noted by Matyas (1992b): "Unfortunately, many institutions' selection of problem areas to target are not based upon actual data pinpointing specific problems in their institutions" (p. 45). Analysis of such data is essential in targeting programs effectively. For example, data from several U.S. studies has shown that a higher proportion of females than males leave SET subjects during the undergraduate years (NRC, 1991; Seymour, 1995; Strenta, Elliot, Adair, Matier, & Scott, 1994).<sup>4</sup> We were not able to establish whether this is the case in Scotland; the data were not available. We were only able to establish that the proportion of women in SET in higher education continues to diminish as they progress in higher education. The funnel diagram illustrates this.

#### *Persistent Underrepresentation of Women in SET.*

We used three different measures to assess women's participation in science, engineering and technology over time: the number of women studying SET ( $F$ ), the proportion of those studying SET who are women ( $F/(F + M)$ ), and the SET parity index ( $F/[\text{total } F]$ ). Each of these statistics is an indicator of women's participation in science, engineering and technology, yet each yields very different results, particularly when examining trends. For example, the increase in each of these three statistics between 1981–1982 and 1993–1994<sup>5</sup> at Scottish HEIs is 76%, 31%, and 9%, respectively (Universities Statistical Record, 1994).

First, there is no doubt that the absolute number of women studying SET subjects has increased over the past several years. Between 1981–1982 and 1993–1994, the numbers of both female and male undergraduates in science, engineering and technology increased by

<sup>4</sup> Some of these studies point out the puzzling nature of these findings, as there is evidence that women enter science, engineering and technology degree programs with higher average performance scores than their male counterparts (see Seymour, 1995).

<sup>5</sup> In 1994–1995, HESA took over responsibility for reporting higher education statistics from Universities Statistical Record (USR). Owing to differences in categorization and reporting, USR data (up to 1993–1994) are not entirely consistent with HESA data (1994–1995 and later). In this article, therefore, HESA data are used for single-year reporting, while USR data are used for trend analysis (as advised by HESA, April 1997).

76% and 19%, respectively. Male science undergraduates still outnumber female science undergraduates, but the gap has narrowed. To put these participation figures in context, this period has also been one in which enrolment in higher education in Scotland, as in the rest of the United Kingdom, has risen dramatically, particularly by women. During this same period, the number of female undergraduates in higher education in Scotland increased by 61% (to 27,685), compared with an increase of 35% (to 30,952) for male undergraduates. We need a more sophisticated analysis than looking simply at enrolment figures to assess the increase in women's participation in higher education which is specific to science, engineering and technology.

Most studies of the underrepresentation of women in SET make use of the second statistic defined above as a measure of women's participation rates, i.e., the proportion of those studying SET who are women ( $F/[F + M]$ ). Intervention programs often cite increases in this proportion, particularly in engineering, as a measure of their success (Engineering Council, 1995). For example, the proportion of women engineering and technology undergraduates in Scotland doubled between 1981–1982 and 1993–1994, from 7% to 14%. There are two reasons, however, to use this statistic with caution. First, changes in “the proportion of those in SET who are women” are determined not only by increases in the participation rates of females, but also by decreases in the participation rates of males. Second, after increasing consistently throughout the 1980s, the participation rate of women in engineering has remained virtually constant at 14–15% in Scotland since 1989–1990. This is consistent with findings from several other countries (e.g., the United States, Australia, Sweden, and the Czech and Slovak Republics) which show that participation rates of women students in engineering have levelled off, and in some cases started to decline, in recent years.<sup>6</sup>

The third measure of women's participation that we examined was the SET parity index (see also Barber, 1995; National Science Foundation, 1984). This is a measure of the number of female SET undergraduates as a proportion of all female undergraduates (e.g.,  $F/[total\ F]$ ). We employed the SET parity index to express the participation of women in science, engineering and technology in a way that is not biased by overall increases in women's participation in higher education or variation in the participation rates of males. In other words, analysis of trends in the SET parity index shows how much more likely it is for women to study SET subjects. Figures 2 and 3 show trends in the SET parity index for both female and male undergraduates in science and engineering/technology, respectively.<sup>7</sup>

Figure 2, the science parity index, shows that the proportions of both women and men studying science subjects declined slightly in the mid-1980s, but since then all change has been toward an increase in participation by both women and men. Among men, the percentage studying science over the period 1981–1982 and 1993–1994 declined from 25% to 23% of all male undergraduates. Over the same period, among women the percentage rose slightly from 20% to 21%. In other words, 20% of all female undergraduates studied science subjects in 1981–1982, compared with 21% in 1993–1994. Also, since 1981–1982 the science parity index curves for women and men have followed the same trends, implying that changes in participation in science since 1989–1990 have not been gender specific.

<sup>6</sup> See Brown and Joslin (1995), Byrne (1993), McIlwee and Robinson (1992), Morgan (1992), Slunaska (1994), and Ullenius (1994).

<sup>7</sup> For a more detailed breakdown of the parity index across SET subject areas, please refer to Cronin et al. (1997).

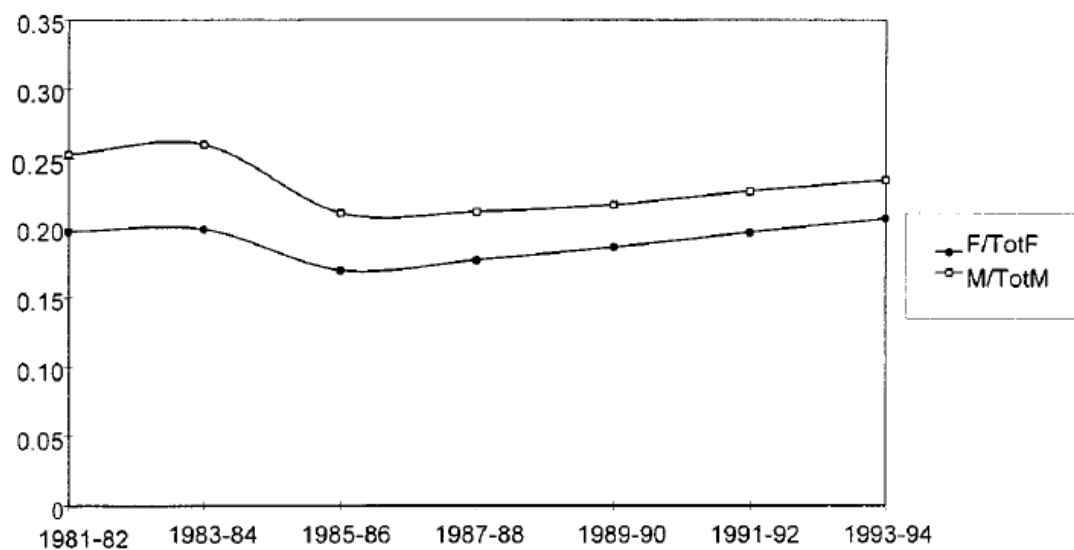


Figure 2. Science parity index for undergraduates, Scotland, 1981–1982 through 1993–1994

Figure 3 shows the engineering/technology parity index for the period 1981–1982 to 1993–1994. The percentage of male undergraduates studying engineering or technology fell from 21% to 18%, remaining constant at 18% since 1989–1990. The percentage of female engineering/technology undergraduates stayed remarkably constant: 2.1% in 1981–1982, and 3.2% in 1993–1994. After an initial increase from 2.1% to 2.8% between 1981–1982 and 1983–1984, the engineering/technology parity index barely increased (0.5%) over the next 10 years. Thus, while the number of women studying engineering/technology has increased and the proportion of engineering/technology undergraduates who are women has increased, *the proportion of women undergraduates studying engineering/technology has remained steady.*

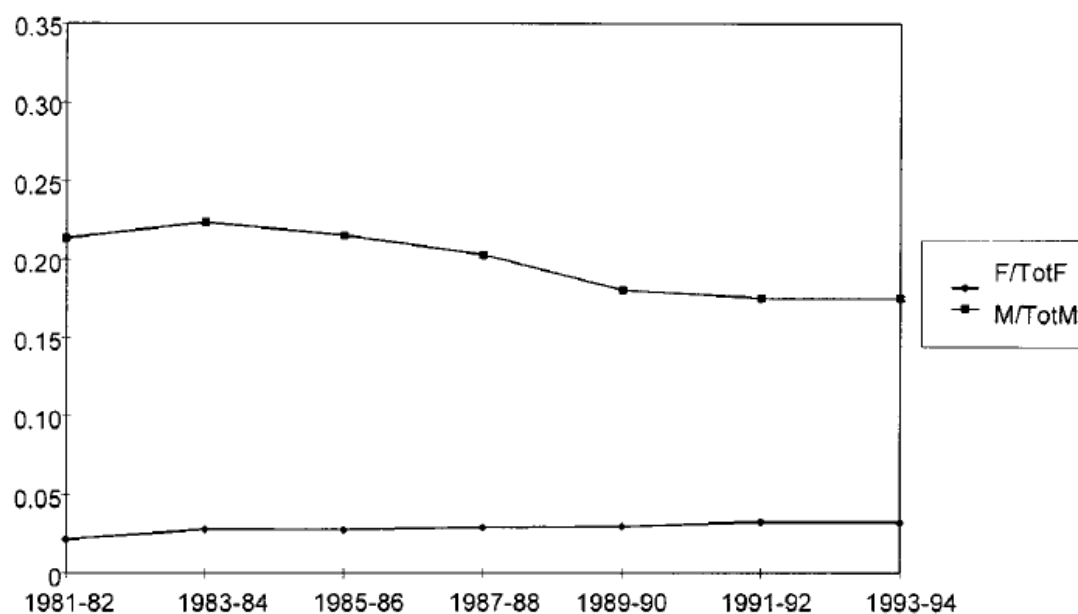


Figure 3. Engineering and technology parity index for undergraduates, Scotland, 1981–1982 through 1993–1994

The numerous interventions for girls to consider engineering as a career have been successful, then, only in keeping the proportion of women in engineering and technology relatively constant. This is not to undermine the value of these initiatives; they are an important enabling step, as we will argue later. The fact remains, however, that no significant inroads have been made in making engineering and technology degrees a more popular choice for girls or women overall. Also, as in the case of science, the parity index curves for women and men have been similar in shape since 1989–1990, indicating that changes in participation since this time have not been gender specific.

Thus, in terms of the likelihood of women choosing to study and remain in SET, the status quo has been maintained rather than challenged over recent years. We found both the funnel diagram and SET parity index to be useful tools in defining and characterizing the underrepresentation of women in SET, helping to establish the rationale for action to be taken. However, while they each illustrate both the progressive and persistent underrepresentation of women in SET in higher education, respectively, neither addresses the question of why this is the case. Our next step was to seek to understand the possible causes of women's underrepresentation in science, engineering and technology.

### ***Exploring the Reasons for Women's Underrepresentation in Science, Engineering and technology in Higher Education***

Although women's underrepresentation in SET may be quantified, its precise causes are less easily grasped. Such an understanding is essential, however, in designing and implementing effective strategies to increase women's representation. As we defined earlier, good practice can be assessed only with a clear understanding of the nature and causes of the problem being addressed, and an examination of its effectiveness in bringing about improvement.

A review of the literature (national and international), confirmed by a small survey of women at Scottish higher education institutions, revealed a variety of reasons for women opting out of or experiencing difficulty within science, engineering and technology at various points along their educational paths or academic careers. These included:

- The image of SET subjects (e.g., masculine, concerned with things rather than people), particularly in engineering, computing and physics
- The stress and isolation of being in a minority
- Negative attitudes of male peers, lecturers and other staff
- Narrow course content
- Didactic teaching approaches
- Lack of opportunities for cooperative or interactive learning
- Emphasis on individual competition
- Inadequate counselling and advising
- Concerns about combining a SET career with having a family

As suggested by many authors, the causes of women's underrepresentation in SET appear to be a complex web of interdependent factors, such as those listed above.<sup>8</sup> In addition, reasons for women's attrition from SET subjects differ at various levels of study and career progression, and these issues must be examined by specific SET disciplines. There is, however, little enthusiasm among many in higher education for such an explanation.

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<sup>8</sup> See, for example, Etzkowitz, Kemelgor, Neuschatz, & Uzzi (1994), Hewitt and Seymour (1991), Rayman and Brett (1995), Rosser (1990), Seymour (1995), and Tobias (1990).

Particularly in science, engineering and technology, many practitioners would prefer a simpler diagnosis of the problem, and hence more straightforward solutions. We considered this to be a significant obstacle: inaccurate and/or incomplete perceptions of the reasons for women's underrepresentation in SET.

The most common perception by many SET academic staff is that we simply need to attract more women into science, engineering and technology. In most cases, this view is allied with a tendency to locate the causes of the problem outside higher education. When inequality in participation and progression within higher education is pointed out, it is most often seen as the fault of schools, of society in general, or of women themselves—rarely the inadequacy or responsibility of individual departments or institutions (Byrne, 1993; Scottish Wider Access Programme, 1993; Thomas, 1990).

Our research showed that while working to increase access, i.e., getting more women into SET in higher education, is indeed a necessary step in increasing their overall participation, it is insufficient in itself to make a significant impact. Quantitative evidence indicates that many women leave SET—during their courses, after earning an undergraduate degree, even after beginning an academic career—and many who remain in SET experience particular difficulties (as outlined above). Clearly, there is more effort needed beyond getting more women in the door.

The funnel diagram helped us to visualize and communicate this problem. The proportion of women is reduced at every stage of the funnel when, for a wide variety of reasons, women opt out of pursuing an SET education or career any further. Increasing access to these subjects in higher education—in effect, widening the funnel opening—will permit more women to enter SET, but is no guarantee that they will progress further. Initiatives to increase access must also be accompanied by initiatives to address the problems women experience throughout their academic careers, i.e., widening the funnel at every stage.

As our own understanding of the problem deepened, we set out to survey Women in SET initiatives, expecting to find a wide variety of types of initiatives with varying levels of success. This would give us the raw material to go on to identify examples of good practice.

### *Surveying Women in SET Initiatives*

In our efforts to identify examples of good practice in Women in SET initiatives, we undertook a comprehensive survey using electronic as well as conventional sources. We uncovered descriptions of a wide variety of initiatives which have been implemented in various countries. In addition, many more initiatives were brought to our attention which had never been formally documented in the public domain.

During the course of our research, we met regularly with advisory groups whose role was to provide feedback on the content of the guides being produced. Each of the three strands of the Winning Women project (access, participation, and progression) had its own advisory group of approximately 20 members. Each group was composed primarily of representatives from each of the 14 Scottish HEIs offering SET degrees; most of these were academic staff from science and engineering departments. Other members included representatives from a range of businesses and industries in Scotland, and other interested organizations, and individual scientists, engineers, and technologists. Many advisory group members were female lecturers in science or engineering, most of whom gave us valuable information about

their past and ongoing efforts to understand the patterns of and reasons for women's underrepresentation in their departments, to increase girls' and women's access to SET subjects, and to support women students and academic staff. The results of many of these efforts have never been published; the information has thus not been available to a wider audience.

Several reasons were put forward for this dearth of published material documenting Women in SET initiatives. First, the majority of these initiatives were (and continue to be) organized by individual women already working full-time as SET academic staff, often with minimal or no formal funding for their work in this area. As noted widely in the literature, in the absence of institutional commitment to support this work, it is primarily individual women who fill the gap (Byrne, 1993; Matyas, 1992b). In the midst of demanding work schedules, the documenting and publishing of efforts to improve the educational experience for women in SET usually falls secondary to doing the actual work.

Another difficulty is the pressure to publish in one's field. While the results of Women in SET initiatives (and other gender-related research in SET disciplines) are clearly of interest and value to a large audience, they are not generally regarded as valid topics for publication within SET departments under pressure to meet competitive publication targets. This is especially the case in the context of the recent (and probably future) research assessment exercise (RAE)<sup>9</sup> in the UK higher education sector. Whether and where such work is published is a key issue. If the work is not published in mainstream science, engineering, or technology journals, not only will the researchers (and thus their departments) not receive credit for the work, but the work will not be made available to those in the particular SET discipline which it seeks to affect. Such work is easily marginalized and ignored, as may be those who conduct this work.

The unavailability of comprehensive information on Women in SET initiatives posed two problems for us as researchers. First, we had no measure of the full extent of these activities in higher education in Scotland, let alone beyond Scotland. Second, with comparatively few initiatives published, comparison of differing approaches proved difficult. However, the available information on Women in SET initiatives proved helpful in characterizing the various types of initiatives, allowing us to explore these in greater depth, including examining the evaluation results of such programs.

To identify good practice and to inform it on an ongoing basis, evaluation of Women in SET initiatives is essential. The existence of a program or initiative does not imply it is effective. Initiatives designed and implemented with the best of intentions may have no impact or may even have negative side effects, such as alienating or patronizing the girls or women at whom they are aimed. For a number of reasons, few Women in SET programs or initiatives have been the subjects of objective, valid, and reliable evaluations (Brainard, 1992). Any of several factors can prevent an effective program evaluation: inaccurate or unavailable statistical data, inadequate program design, lack of resources, fear that unsuccessful results will have negative implications for future program funding, and lack of understanding or acceptance within SET of evaluation methods and results.

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<sup>9</sup> The research assessment exercise in the U.K. higher education sector publicly labels departments and institutions on a 1–5 scale, and future funding for research is allocated on the basis of this rating. Increased competition between departments and institutions for funding has led to a struggle for publication (Nisbet, 1995).

To assess the effectiveness of programs which aim to increase the representation of women in SET in higher education, statistical information is often the simplest indicator of change. However, stated measures of success may vary widely. Many Women in SET programs, for example, cite an increase in the proportion of women studying SET as a measure of their success. Although this is an indication of positive change, this does not take into account other changes such as changing numbers of male SET students and changing numbers of women in higher education overall (see earlier discussion of SET parity index). In addition, some of the data required to fully explain women's participation in SET in higher education, e.g., identifying the points at which women students leave SET, and their destinations, are simply not collected in sufficient detail by most HEIs. Analysis of such data is essential in targeting programs effectively. In any case, even if one could readily obtain accurate statistical data, they would not tell the whole story. The reasons individuals choose to continue, change, or terminate their study in SET subjects would not be revealed.

Qualitative evaluation techniques are the best option for capturing information on students' reasons for their choices, their experiences as students and members of staff, and their reactions to various initiatives and intervention strategies. The skills required to conduct qualitative evaluations are generally found outside SET departments, more likely in departments of social science, psychology, education, or women's studies. Thus, effective design and evaluation of Women in SET programs require multidisciplinary teams to carry out the work. There are huge obstacles to achieving this, since academic staff in SET departments tend to undervalue and even to dismiss these skills (Thomas, 1990). More significantly, the demands of the RAE have discouraged multidisciplinary research and will continue to do so unless the rating criteria are changed. Furthermore, the legitimacy and acceptability of critiques of science practice from outside science are currently a hotly contested issue—in the United States, the United Kingdom, and elsewhere in Europe (Sokal and Bricmont, 1998).

To summarize, then, the main difficulties we encountered in seeking to identify examples of good practice in Women in SET initiatives were lack of acknowledgment of the underrepresentation of women in SET in higher education; lack of data to adequately describe women's access, participation, and progression patterns; inaccurate and/or incomplete perceptions of the problem; failure to accept responsibility within higher education for women's underrepresentation; lack of data on Women in SET initiatives; and lack of evaluation results. We concluded, therefore, that it would not be possible to create a straightforward list of examples of good practice in Women in SET initiatives as we had defined it. We needed to find a way of understanding how various initiatives sought to address the underrepresentation of women so that we could identify those initiatives most likely to be effective.

### **Developing a Conceptual Framework**

In formulating and presenting our findings, we faced a dilemma: how to categorize and then assess different initiatives which address women's underrepresentation in SET in various ways. Generally, there appeared to be three main types of initiatives: those which seek to encourage girls and women to consider/enter SET; those which aim to support women who are already studying or pursuing careers in SET; and finally, those which aim to change SET teaching and culture so as to make it more inclusive. These various approaches seemed to be rooted in different perceptions of the problem of women's underrepresentation.

How could we, for example, assess the comparative effectiveness of “women-into” activities designed to improve women’s access to SET, mentoring programs to support and encourage women in SET, and programs of curricular and pedagogical innovations seeking to change the practice of SET education? The goal of all three types of initiatives is long-term change—difficult to quantify and evaluate. In addition, philosophical differences underlie these diverse approaches. Various “women-into” initiatives assume that science, engineering and technology are good places for women to be, and that more women should be encouraged to enter these fields. Support programs such as mentoring assume that women require and deserve extra efforts to persist and progress in science, engineering and technology. The third type of initiative, working to change course content and teaching approaches, advocates changing the practice and culture of SET itself to attract more women (and other currently underrepresented groups). Are these three approaches contradictory or complementary methods of achieving the same end, i.e, improving the position of women in science, engineering and technology in higher education? We developed a conceptual framework of positions on women in SET to consider this question.

In considering the effectiveness of various initiatives, we sought to classify and compare them on the basis of their perceptions of the problem being addressed, as we had learned that these varied considerably. We were able to identify five distinct positions or rationales. All initiatives to address the underrepresentation of women in SET can be seen to originate from one or more of these positions. We formulated a conceptual framework that enabled us to locate these five positions according to their assumptions about science, technology, and gender (Table 2). The five positions in the framework represent, loosely, a chronological progression of the main approaches to women’s underrepresentation in SET during the past 20 years.

Each of the five positions is examined below, detailing the assumptions of each position, the types of actions proposed to address women’s underrepresentation, and critiques of the limitations of each position.

### ***Position 1: Foster Public Understanding of SET***

Position 1, “Foster public understanding of SET,” holds that science and technology are both (a) inherently objective and value neutral, and (b) misunderstood by many. Thus, science and technology should be presented to the general population in a more positive and accessible manner. Most adherents of this position believe that more able and talented people of both sexes are required in science, engineering and technology. Because science itself is objective, there should be no differences between the contributions of male and female scientists, engineers, and technologists. The actions proposed by advocates of this position include publicizing science, engineering and technology as useful, progressive, and benevolent, thus encouraging more people, both female and male, irrespective of class or ethnicity, into SET.

Critics of this position have noted that—despite its egalitarian claims—this approach assumes that scientists are the experts and the public is ignorant: an “us and them” approach in which the expert scientists are being misunderstood (and misrepresented) by an ignorant and emotional laity (Irwin & Wynne, 1996). Furthermore, rather than it being a question of the public lack of information and misunderstanding of science (that somehow it is merely the image of science that is incorrect), there is evidence that the public is informed about many aspects of science and technology, and rejects some of them as unacceptable. For example, some of the questions science asks, and the uses to which it is put—such as military

Table 2. Conceptual framework of positions on women in science, engineering and technology

Position	Assumptions			Actions Proposed
	Science & Technology	Gender	View of Women in SET	
1. Foster public understanding of SET	Objective and neutral	No central to analysis	Need more able people in SET; no difference between contributions of women & men	Publicize SET as useful, progressive, benevolent
2. Recognize SET's economic contribution	Objective and neutral	No central to analysis	Women's talents represent an underused human resource in SET	Mass higher education with more SET, wider access, vocational emphasis
3. Promote equality of opportunity	Objective and neutral	Recognize structural obstacles to equality	Women entering SET break down stereotypes	Encourage girls and women into SET; other equal opportunity programmes
4. Subject SET to critical analysis	Socially constructed, cannot be neutral	Standpoint of those outside of societal power is unique and valuable	Question whether women should enter SET as is	Critical analysis of SET (from within and outside)
5. Change SET culture	Socially constructed, cannot be neutral	In white, western culture masculinity is equated with technical competence, femininity is equated with lack of technical competence	Potential conflict for women between feminine gender identity and masculine culture of SET	Change system rather than change women to fit system; change SET culture to be more inclusive of all

oppression, exploitation of developing countries, and the abuse of animals—are known and understood but are rejected by many (Rose, 1994; Spanier, 1995). Rather than the image of science being off-putting, and by implication, only the image which needs to be corrected, it is what really happens that turns people away from it (Henwood, 1996).

Position 1 is also criticized for its failure to theorize a gender dimension. Insofar as it addresses women's underrepresentation in SET, it does not seek to explain why women might be underrepresented in comparison with men. It is marked by the uniform treatment of males and females, the goal being to make science, engineering and technology more appealing and attractive to all. This ignores the way that the representation of science as abstract and disembodied is less likely to be interesting to the more person-centred individual, especially women (Keller, 1985; Rose, 1994). Women's ways of knowing are often represented as more concerned with the concrete, everyday world, and more connected to and responsive to the environment (Code, 1991) and appear more concerned with the social responsibility of science (Shepherd, 1993).

Position 1 has also been criticized for regarding the problem as caused by outside influences—such as socialization of girls away from science in the home and at school; insufficient career information; the heavy and dirty image, especially of engineering; and the view that science, engineering and technology are not creative subjects<sup>10</sup>—rather than as a problem for SET itself (Henwood, 1996; Smithers & Zientek, 1991).

### ***Position 2: Recognize SET's Economic Contribution***

The “Recognize SET's economic contribution” position, also assuming science and technology to be objective and value neutral, considers developments in these areas to be essential for the nation's global economic competitiveness. Like Position 1, this position does not differentiate among the contributions of female and male scientists, engineers, and technologists. Actions motivated out of this position have included the move toward mass higher education, more emphasis on science and technology in education curricula, wider access to higher education, and a vocational emphasis in education and training. It is believed that such actions will enlarge the pool of talent from which tomorrow's successful scientists, engineers, and technologists will be drawn, thus ensuring the nation's continued economic competitiveness in the global economy.

Position 2 draws on human capital theory, which treats education as a form of investment. It has long been accepted that high levels of investment in education are needed for economic growth (Schultz, 1960). Denison (1962) also posited that because improved education raises the quality of labour, education “causes” economic growth.<sup>11</sup> Some educational policy analysts have argued, however, that the Schultz–Denison model of growth is flawed and that the supply-side human capital approach is doomed to failure: The supply of educated labor cannot create jobs (Levin & Kelly, 1997; Marginson, 1993). The problem, on the other hand, is a failure of advanced economies to make productive use of educated labor. Despite such criticisms, the common sense of human capital theory remains largely unquestioned, so that

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<sup>10</sup> The Millennium Commission in the United Kingdom has expressed disappointment to COPUS at the small number of science-related proposals it received, an indicator that science and technology are not considered creative fields by large sections of the population.

<sup>11</sup> The *Nation at Risk* report, for example, implied that the economic performance of West Germany and Japan could be attributed to the higher performance of its students in tests in international comparisons (National Commission on Educational Excellence, 1983).

when hopes for the economy in a climate of global competition seem to depend increasingly on science and technology, investment in scientific and technological education is seen to be the key to economic growth.

Insofar as this position addresses the underrepresentation of women in science, engineering and technology, again there is no explanation of why such underrepresentation exists, it simply strives to get more women in. The European Union's modernization project, known as Scientific and Technological Europe, considered women to be a hidden reserve in the techno economic project of catching up with Japan and United States (the U.S. formulation of this argument cites Western Europe and Japan) in terms of technological innovation and economic growth (Rose, 1994). However, they simply cast the problem of the underrepresentation of women in SET as a question of increasing the flexibility of the labor market and skills training. Henwood (1996) criticized the lack of explanation for the underrepresentation of women in such initiatives as WISE, an initiative launched in 1984 in the United Kingdom which has promoted hundreds of large and small initiatives to encourage girls and women into SET. Henwood cited WISE's claim that the nation's "desperate need" of scientists and engineers at a time when the number of school leavers was tumbling could only be solved by recruiting more girls. She implied that this representation of girls as the "only source" also implies that women are the "last resort." Furthermore, she argued that the "needs of industry" were certainly paramount in these initiatives rather than concerns for social justice.

A second gender-differentiated aspect of Position 2 is the status of the subjects and perceptions of the economic rewards that such careers can bestow. Evidence in Henwood (1998) suggests that women who choose SET subjects are consciously preparing for men's work, which has a higher status and a greater economic reward than women's work. In the United States, under a quarter of the doctorates in science are earned by women, and those areas where women are concentrated are the lower status, lower paying, and less secure jobs (Erwin & Maurutto, 1998, citing Byrne, 1993; NRC, 1994). In part, the differential salaries of women and men scientists in higher education can be accounted for by the differential rewards bestowed upon research and teaching: Women are more likely to find themselves in subjects where teaching is a priority, affecting their publication rate, whereas research reaps richer rewards in terms of promotion and tenure (Matyas, 1985; Rose, 1994). The rate of attrition of women in the upper ranks of science and engineering also exceeds that of their male counterparts. Erwin and Maurutto (1998) cited evidence that women from minority groups experience even more pronounced inequities in education and career opportunities.

As in the "Public understanding of science" position, advocates of Position 2 often see the problems as lying outside of SET, favouring explanations that turn upon early socialization or innate ability. What this position fails to address most strikingly is the attrition rate of women in the sciences. Despite the numbers of technically competent and scientifically well-qualified women entering higher education, relatively few proceed to higher levels (Erwin & Maurutto, 1998; Keeves & Kotte, 1996).

### ***Position 3: Promote Equality of Opportunity***

The "Promote equality of opportunity" position marks a shift in the theoretical formulation of the problem of women's underrepresentation in SET. While still viewing science and technology as inherently objective and value neutral, this position includes an analysis of

gender in its assessment of the problem, primarily focusing on structural obstacles to women's equity.

Historically, this position represented a major leap forward in how the underrepresentation of women in SET was perceived and addressed. The sex/gender system<sup>12</sup>, which structures inequalities of virtually all social life, is recognized as constituting a major part of the problem of women's underrepresentation in SET. The general view is that while boys are socialized to aspire to scientific and technological activities and careers, girls are socialized to aspire to traditional female roles such as mothering and the caring professions. The masculine stereotypes of science, engineering and technology do not tend to attract girls and women, and perhaps more important, stereotyped notions of women's abilities, interests, and potential serve to justify their exclusion from progressing in science, engineering and technology, particularly at higher levels.

Theoretically, this position is related to that of feminist empiricism, as first identified by Harding in her study of feminist epistemologies of science, *The Science Question in Feminism* (1986). Harding noted how feminist researchers in biology and the social sciences had identified sexist and androcentric research findings which were the direct result of bias on the part of male scientists (for example, making generalizations about humans based only on data about men). However, feminist empiricism defends the methods of science, believing they can be used to correct the errors produced by gender ideology.

Adherents to Position 3 believe that more women should enter SET, both to fulfil their own potential and to help break down the existing masculine stereotypes of scientists and engineers. Social justice and equal opportunities arguments are used to justify offering girls and women the same opportunities as males in pursuing careers in SET. This position is related to similar liberal approaches in other areas of society—education, business, and law—where it is argued that special efforts are needed to allow equal numbers of women to enter and progress in historically male-dominated fields.

Initiatives for increasing the representation of women in SET, motivated by these concerns, include media campaigns to change the image of science, engineering and technology, Girls into SET and Women into SET programs, and the provision of role models, mentors, and career information and guidance for women. While such initiatives have been in place for several years now, and have certainly afforded many individual girls and women with valuable opportunities to learn about and embark upon careers in SET, it must be said that these efforts have been largely unsuccessful in greatly increasing the proportion of women studying and teaching SET in higher education (Figures 2 and 3).

Critics of this position identify several reasons why this may be so. The main criticism of Position 3 is that it operates from a deficit view of women, i.e., a tendency to see women as the problem. Because this position aims to get more women into SET, the emphasis is put on girls and women to take up opportunities in science and engineering. Such a position ignores the experiences of many women in SET who are marginalized, discriminated against, and even harassed in an overwhelmingly male-dominated environment (Devine, 1992; Erwin & Maurutto, 1998; Hall & Sandler, 1982; Narek, 1970; Spanier, 1995). Much evidence exists to show a general hostility toward women in engineering and technology, in particular (Carter &

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<sup>12</sup> Code adds: "The 'system' manifests itself differently in different social and political groups; it varies along economic, racial, religious, class and ethnic lines. But some such system is in place in every known society, where it functions to produce relations of power and powerlessness" (1991, p. 68).

Kirkup 1990; Cockburn, 1985; Hacker, 1989; Kirkup & Smith Keller, 1992; Wajcman, 1991). Thus, girls and women are encouraged to adapt to fit into SET, rather than challenging the masculine culture of science and technology—in other words to cope in SET, as is.

Henwood (1996), citing Devine (1992), argued that equal opportunities approaches are interpreted by management in the short term by “fixes” at the point of entry (e.g, changing selection procedures) rather than permeating the culture of the workplace and addressing all constraints facing women in a male-dominated environment. Citing considerable research evidence in support of her argument, Henwood characterized the equal opportunities approach as “short” and “liberal” rather than “long” and “radical.”

Position 3, like other liberal feminist approaches, has been criticized for setting equality as the goal for women. Equality implies acceptance of existing norms and standards, something which its critics consider an unsatisfactory goal for women. A deeper analysis of equality in educational policy by Lips (1990, p.19) explored the notion that equal treatment may produce vastly different results: “What is taken to be equal treatment may only appear to be equal or fair because of an unacknowledged linear assumption that the ‘same to each’ (treatment equity) is synonymous with the ‘same for each’ (effects or results equity).” Furthermore, any attempt to offer special treatment to women marks them as different and deficient (the root of the problem) and offends against the principle of “equal opportunities” in obtaining unwarranted favour (Henwood, 1996). In addition, as with other liberal policies, approaches arising from Position 3 are often seen as focusing too heavily on the concerns of white, western, middle-class women, rather than women of all races, cultures, and classes, and underrepresented male groups.

Another major criticism of Position 3 (as well as the earlier positions) is that it fails to subject the fields of science, engineering and technology to critical analysis. During the past 20 years, a rising tide of critical analysis has challenged science’s claims to objectivity and neutrality. There exist many criticisms of the contention that the scientific community is representative of the gender, racial, or class diversity in society, and therefore of the possibility that it can be objective and neutral, or that the context in which studies are undertaken is neutral (Birke, 1986; Fausto-Sterling 1992; Gould, 1981; Haraway, 1989; Hubbard, 1988; Merchant, 1980; Rose & Rose, 1976; Rose, Lewontin, & Kamin, 1984). Drawing on work by Harding (1986) and Hubbard (1988), Duran stated it bluntly: “contemporary science’s failure to acknowledge that it, too, is driven by social forces beyond its control and is responsive to social conditions that it pretends to ignore leaves us with science-as-lie” (1991, p. 92). In particular, Position 3 leaves the masculine values, theories, practices, and culture of science and technology untheorized and unchallenged.

Despite these criticisms, Position 3 can be seen as an essential step in the evolving understanding of the issues, enabling more long-term or radical approaches, such as those described in Positions 4 and 5.

#### ***Position 4: Subject SET to Critical Analysis***

The fourth position, “Subject SET to critical analysis,” also represents a major leap forward in how the underrepresentation of women in SET is perceived and addressed. Position 4 addresses the fundamental shortcomings of Positions 1–3 in that it shifts the focus of analysis to SET itself; science and technology are no longer considered to be neutral and objective.

Women's underrepresentation in SET is considered to be largely the result of inherent bias within the social construction of science, engineering and technology.

This position is related to feminist standpoint epistemology as first identified by Harding (1986), drawing on work by Rose, Hartsock, Flax, and Smith. In essence, the standpoint approach holds that "there is no one position from which knowledge can be developed, but some positions are better than others" (Longino, 1996). In particular, in societies where power is organized hierarchically—by race, class, and gender—the view of reality from the perspective of the powerful is more partial and distorted than that available from the perspective of the dominated. According to feminist standpoint theory, then, women's subjugated position offers them a perspective different from and more complete than that of males. Science and engineering incorporate stereotypically masculine values, practices, and cultures—because of their history, practitioners, and locations. It is not surprising, then, that many more women than men resist entering SET and leave it more readily, since their vision of science/technology must be struggled for (Hartsock, 1983) and therefore their place in it precarious.

Position 4 can be viewed, historically and conceptually, as an essential step in moving from Position 3 to Position 5. Harding herself wrote: "It is true that first we often have to formulate a 'woman-centered' hypothesis in order to comprehend a gender-free one" (1986, p. 138). Adherents of Position 4—and their proposals for change—are varied, ranging from separatists, who believe women should reject science and technology "as is," to reformists, who believe women can and should enter SET so that it can be reformed. Separatists consider that because the social structure of SET is biased, adding more women into the field will only strengthen divisions of class and race among women. These theorists often criticize specific technologies and applications of science, such as military and reproductive technologies, and advocate the development of a new sort of science, one which is woman-centered or "gynocentric" (Bleier, 1984; Hubbard, 1988). Although such a position addresses many of the criticisms of Positions 1–3, in that it attempts to theorize gender as well as recognize science and technology as socially constructed, it has many critics. Most target its tendency toward biological determinism and to overlook differences among women (Duran, 1991; Harding, 1986; Longino, 1996). Those who advocate gynocentrism or separatism have been criticized as being unrealistic: How can science and technology change if women do not enter these fields to change them? Such a position leaves little space for negotiation or resistance (Longino, 1987).

Some advocates of Position 4 believe that by entering the existing science, engineering and technology professions, women could create better, more inclusive science and technologies, based on their unique standpoint (Harding, 1991; Longino, 1987). Many of these draw on and develop feminist standpoint theories, while others have developed more sophisticated feminist empiricist philosophies (Longino, 1996). Whatever its epistemological roots, however, this stance aims not simply to substitute "women-centered" for "man-centered," but rather to provide "a basis for a more accurate understanding of the entire world" (Riger, 1992, p. 733). It is this approach which leads directly to Position 5.

One of the strengths of Position 4 is its inclusion of reflexive practice as part of the task of critical analysis. Not only are the assumptions, practices, and cultures of SET subject to analysis, but past and present projects advocating change for women are also examined. As Rose (1994) noted, liberal approaches to increasing the representation of women in SET—those we have identified as arising from Position 3—such as WISE and Girls into Science

and Technology (GIST) have been justly criticized in feminist circles. Rose (1994) cited the notable example of Alison Kelly, of the GIST project in the United Kingdom:

Alison Kelly, as the sociologist within the GIST study, subsequently wrote an autocritique of her 1982 paper in which she largely accepted the structuralist view of education and the feminist critique of the sex/gender system. She wrote, "I would put more emphasis on the role of the schools in dissuading girls from science, and less on the girls' internal states. The article suggests that it is necessary to change the image of science. I now think that it is necessary to change *science*" (Kelly, 1985, p. 114).

Whatever the actions proposed, however, this perspective considers critical analysis and the development of theories about science, engineering and technology to be essential in effecting change. These, it is believed, should be initiated both within and outside SET. As Lorraine Code wrote, "the purpose of feminist critiques is to reveal the limitations of the methodology, to open possibilities of theoretical and methodological pluralism" (1991, p. 159).

### ***Position 5: Change SET Culture***

The fifth and final position we identified in the conceptual framework is to change the overall culture of science, engineering and technology, i.e., "Change SET culture." This position is rooted in the same basic assumptions as Position 4, and essentially springs from feminist critiques of SET. The emphasis here is on creating a more inclusive SET culture and learning environment, notably in higher education.

Position 5 is based on a critical understanding of the dialectic between the social construction of science/technology and gender. Theorists have pointed out that women's alienation from technology, in particular, is a product of the historical and cultural construction of technology as masculine. Within the western or Eurocentric view, technical competence constitutes an integral part of stereotypical masculine gender identity, and masculinity is constructed partly through technical competence. As a corollary to this, the idea that women lack technical competence is a powerful sex stereotype in Western culture, and lack of technical competence constitutes an integral part of feminine gender identity (Cockburn, 1985; McIlwee & Robinson, 1992; Wajcman, 1991). As a number of theorists have pointed out, the stereotypes of masculinity in Western society and the stereotypes expected in an engineer or scientist are essentially identical, i.e., to be logical, abstract, nonemotional, independent, active, and competitive (Benston, 1992; Harding, 1991; Kramarae, 1988).

Such an analysis has significant implications for women who enter SET. Women scientists, engineers, and technologists may experience a conflict between their feminine gender identity and the masculine culture of SET (Cockburn, 1985; Turkle, 1984; Wajcman, 1991). This helps explain the extreme gender imbalance in engineering, computing, and physics, as compared with the less technological or hard sciences. In addition, this position addresses the failure of liberal programs for change; i.e., girls and women are seen as actively resisting some sciences and technology for valid reasons rather than having misconceptions about the image of such disciplines.

Actions proposed by adherents of this position suggest a complete reframing of the problem of women's underrepresentation in SET. Women's agency in choosing SET, or not, is recognized: The culture will not be changed merely by the inclusion of more women.

Proposed solutions centre instead on addressing both sides of the conflict between feminine gender identity and the masculine culture of SET. Efforts are endorsed which challenge all forms of gender role socialization (as thwarting the full development of both females and males) and which also challenge the masculine culture of SET.

Actions proposed by Position 5 include curricular and pedagogical changes, as well as training to increase the awareness of SET teaching staff. Proposed curricular changes, designed to appeal to women as well as a larger pool of men, include humanistic and socially oriented features within courses, flexibility in course options, emphasis on communication skills and technology assessment, and history of science/technology (Bennett, 1994; Rosser, 1990). Changes in teaching and learning strategies include the adoption of holistic, participative, and gender-inclusive approaches which can engender an ownership of learning and a feeling of confidence in all students. Specific strategies may include broadening the range of teaching and learning methods, encouraging student interaction, teaching teamwork skills, and making more explicit links between theoretical and practical learning (Moxham & Roberts, 1995; Roychoudhury, Tippins & Nichols, 1995). Some institutions are also currently devoting resources to gender equity training to address the issue of gender equity in the classroom (Cronin et al., 1997, pp. 21–22; Henes, 1994; New England Consortium for Undergraduate Science Education, 1996). To deal with an increasingly diverse student body, teaching staff can raise their sensitivity to avoid gendered and racist language, sexist behaviours and sexual harassment, helping to create a classroom climate that is more conducive to learning.

Position 5 is less studied—and more controversial—than the earlier positions. In their assessment of various approaches to women in SET, however, Gill and Grint (1995) considered this position to be more robust theoretically than earlier positions: The understandings of both gender and science/engineering/technology are sophisticated and the emphasis is on the relation between them. The dilemma posed by comparing Positions 3 and 4—i.e., should we encourage more women into SET or should we critique and reform SET—is answered in the affirmative. Position 5 aims to be a both/and rather than an either/or approach to the problem of women's underrepresentation, incorporating the strengths of Positions 3 and 4.

### ***Reaction to the Conceptual Framework***

The conceptual framework received widespread support from the advisory groups supporting the Winning Women project. Most advisory group members said they found the framework valuable as a larger context within which to consider various Women in SET initiatives. This included both individuals who had and had not instituted and participated in such initiatives in their own universities/departments. A dissenting opinion was held by two scientists who reacted negatively to our description of Position 4 as “subject SET to critical analysis” (criticism being perceived as negative in the scientific paradigm). One member of the Participation Advisory Group, a female lecturer in computer science, responded to the movement or growth in awareness captured in the description of the five positions:

Having been involved in the ‘women into’ line for many years, I realise how we have changed our emphasis, and will continue to do so. A solution for today is not one for tomorrow. That does not mean either that previous ways were wrong, but we have developed a movement during the process, and have been adapting in the light of experience and culture.

Based on this positive feedback from our advisory groups, especially the key participants who would be likely to implement the findings of the Winning Women research project in their own institutions, we considered this conceptualization to be a central element of our research findings. Our view, supported by the advisory groups, was that the conceptual framework would allow various types of initiatives to be considered, and their likely impact assessed, to make best use of limited resources to effect positive change.

The conceptual framework was not accepted by the project funders, however. Despite our efforts to ground our findings by establishing the basis of the problem we were addressing, through quantification and explication of its nature theoretically, these were rejected as being too academic and too critical for the purposes of the project.<sup>13</sup> The discussion which ensued between the funders and researchers made it clear that the definition of good practice which the researchers had used was not one shared by the funders. They did not favour our making judgments about the value or likely effectiveness of any initiative. In effect, dialogue established that what the funders wanted was a catalogue of initiatives which had been tried, an inventory produced in a value-free fashion—in essence, “good practice” defined simply as “practice.” Three guides have been produced to this more limited specification, but with the support of our advisory groups, a concise statement of the philosophy underlying various initiatives, at least, was included in each guide (Cronin et al., 1997; Duffield et al., 1997; Higgins et al., 1997).

## Conclusions

To enable real and lasting change to be brought about in the recruitment into, and retention of, women in SET in higher education, the Winning Women project team gathered accurate and up-to-date data, interpreted them, and presented them in a way which clearly illustrates the extent of the underrepresentation of women. We sought to describe the numerous and interdependent causes of the problem of women’s underrepresentation. We also gathered information about a range of initiatives which have been tried in the United Kingdom and elsewhere. To link these three strands of our inquiry and help us to understand how particular types of initiatives might help, we developed a conceptual framework in which to locate them.

We found the conceptual framework helpful in refining our thinking about the gendered politics of the definition of, and access to, what counts as knowledge in science, engineering, and technology. The framework enabled us to describe various perceptions of the problem of women’s underrepresentation in SET, locate each type of Women in SET initiative, and explain and speculate on its appropriateness and likelihood of success, particularly highlighting possible sources of resistance. As noted earlier, any particular initiative may be seen to be motivated by one or more of the positions identified. For example, many equal opportunity initiatives (Position 3) also stress the broader need for more qualified scientists and engineers so that the national economy can remain competitive (Position 2).

We recognize that certain aspects of the conceptual framework are very controversial, as evidenced by our conflict with the project funders over the inclusion of this analysis in the Winning Women guides. However, we have found it useful in mapping the complex terrain

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<sup>13</sup> Feedback was obtained in various (specified) meetings and communications between the project team and the project funders.

of addressing women's underrepresentation in SET. The framework helps us to explain the intractability of women's underrepresentation. Most of the initiatives which have been tried in the past 2 decades, and which we have demonstrated have not achieved a significant stable increase in the participation of women, in Scotland at least, arise from Positions 1 through 3. They treat the problem as one of a deficit on the part of girls and women, and those who prepare them for higher education. We believe that such approaches are insufficient.

Position 3 represents a fulcrum which permits a shift in emphasis: in a reformulation of Sandra Harding's language, from a "woman problem in SET" (i.e., how can women fit into SET) to "a SET problem for women" (i.e., how can SET become more inclusive of women and other currently underrepresented groups). Position 3, however, has been criticized (particularly in more recent feminist analysis) for being too conservative and not subjecting SET to critical analysis. Harding (1993, p. 53), however, argued that the "radical nature" of feminist empiricism should not be underestimated; its conservatism makes it possible for many people to grasp the importance of feminist research.

Position 4 represents a second key shift in perception of the problem, taking on board the need to subject science and technology to critical analysis, e.g., to recognize how the values and practices of SET serve to exclude women and others. We believe that this step points to a positive way forward for women in SET. Since powerful arguments have been adduced to show how science, engineering and technology have been socially constructed, so, too, can these disciplines be reconstructed to be more inclusive. Researchers who advocate Positions 4 and 5, which begin to subject science, engineering and technology to critical analysis and challenge it to change, are entering a political minefield. Yet, we believe it necessary to open up this important area of debate. At present, we believe that initiatives arising from Position 5 represent the best chance of progress.

We recognize that representing a convincing theoretical chart of the terrain is but one stage in the process of change. Much remains to be done to clear the obstacles to women's full participation in science, engineering and technology in higher education.

### ***Postscript***

In summer 1998, following publication of the Winning Women guides, SHEFC announced that it was to fund developments in the Women in Science, engineering and technology initiative on a rolling basis, supporting the work with £100,000/annum. A prominent theme among the speakers at a seminar held to discuss ways in which to progress the work was that the culture of SET in higher education, indeed the culture of higher education itself, must be changed to enable women's improved participation and progression.

### ***Acknowledgements***

The authors gratefully acknowledge the essential contribution to the development of this work from the other members of the Winning Women project team—namely, Maureen Cooper, Jill Duffield, Cassie Higgins and Sheila Watt. They also thank Janet Stack and David Hartley for invaluable feedback and advice on the manuscript. They are also grateful for the valuable feedback and discussions on early versions of the conceptual framework which they had with several members of the Participation Advisory Group: Jean Barr, Rosemary Candlin, Jim Hewit, Ena Maguire, Ursula Martin, Pennie Ottley, Maggie Pollock and Carol Trager-Cowan.

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