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RESEARCH REPORT

Gender issues related to graduate student attrition in two science departments

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This study explored the gender issues that contributed to the differential attrition rate of men and women graduate students in two science departments (biology and chemistry) at a large research university. Departmental records were used to compute the student attrition rate while surveys from 170 students, and interviews with 32 of them, were used to explore students' perspectives on the reasons affecting the attrition of men and women graduate students in each department. Analysis of the data indicated a significantly larger student attrition rate in chemistry than in biology. In each department the attrition rate for women was also significantly larger than the attrition rate for men. The study uncovered different gender issues, in each department, related to the significantly larger attrition rate for women students.

Introduction

Despite the gains of the past 20 years in the representation of women in scientific fields, their numbers continue to lag behind their male counterparts. In 1999, US universities awarded to women only 15% of the Ph.D.s in engineering, 23% in the physical sciences, and 45% in the life sciences (National Opinion Research Center 2000). These differences increased considerably when the data were disaggregated by citizenship. In these three fields, women of US citizenship earned just 8% of the Ph.D.s in engineering, 14% in the physical sciences, and 31% in the life sciences. This discrepancy is due to the large numbers of foreign students receiving Ph.D.s in science and engineering from US universities. Over the past decade, the number of Ph.D.s awarded by US universities to foreign students has increased at more than twice the rate of Ph.D.s awarded to US citizens, reaching 32% of all doctorate recipients in 1995 (Association of American Universities, 1998). Moreover, the number of Ph.D.s awarded to foreign women has increased by more than 200% (Curtin, Blake and Cassagnau 1997).

Much of the research on the gender gap in science and engineering has focused on the reasons for girls and women's lack of interest and achievement in science. Although investigators (Hall and Sandler 1982, Sandler 1986, Sandler Silverberg and Hall 1996, Meinholdt and Murray 1999) have uncovered some context factors that contribute to the attrition of women from undergraduate science programmes, few studies have examined, in a comprehensive manner, the attrition of women from graduate science programmes.

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According to Hirt and Muffo (1998) 'departments are guided not by institutional standards but by the norms of the discipline' (p. 18). Every Ph.D.-granting department in a university can set its own policies for recruitment, admission, and curriculum requirements (Office of Scientific and Engineering Personnel [OSEP] 1996, Hirt and Muffo 1998). Thus, graduate students' experiences 'are strongly influenced by their department's cultures' (National Science Foundation [NSF] 1998, p. 4). Quantitative studies on graduate student attrition indicate that the department is the best unit of analysis when predicting graduate student completion rates (Berg and Ferber 1983, Ott and Markewich 1985 as cited in Girves and Wemmerus 1988). According to Girves and Wemmerus:

> The department characteristics directly influence doctoral degree progress. The norms and expectations of the faculty vary by department. The nature of the department, including the attitudes of the faculty and the activities that they value and engage in determine, in part, the kind of experience that a graduate student has. (1988: 186)

In non-traditional programmes such as science and engineering, gender issues also influence the climate for graduate students because, as traditionally practiced, science is based on male cultural norms (Eisenhart 1994, Subramaniam and Wyer 1998, Conefrey 2000). Although women are becoming increasingly visible in scientific areas, Eisenhart contends that the norms by which the science world functions continue to be 'prototypically male' (Eisenhart 1994: 193).

Conceptual framework

Researchers have addressed the gender gap in science and engineering from various standpoints. Feminist scholars (Kelly 1985, Harding 1991, Keller 1992, Kleinman 1998) postulate that science has been traditionally portrayed as a male domain, thus making its pursuit by females unlikely. According to Kelly (1985), girls' perception of science as masculine discourages them from expressing interest in science, from doing well in science, and from continuing to study science.

Others contend that girls' perception of science and engineering as male domains is the result of gender-role socialization by family and schools (Kahle 1985, Matyas 1985, Jones and Wheatly 1989, 1990, Jones 1989, Kahle, Anderson and Damnjanovic 1991, American Association of University Women 1992, Shepardson and Pizzini 1992, Sadker and Sadker 1994, Roth 1996). These researchers have found that parents and teachers frequently discourage girls, often unintentionally, from pursuing careers in science and engineering (Kahle 1985, Matyas 1985, Jones and Wheatly 1989, 1990, Jones 1989, Kahle et al. 1991, American Association of University Women 1992, Sadker and Sadker 1994). Parents are more likely to buy scientific games for boys than for girls, and boys are more likely to play with toys that encourage manipulation or construction (Tracy 1987, Oakes 1990).

Studies of classroom interactions indicate that teachers are also more likely to focus their attention on boys, asking them more challenging questions and allowing them to assume leadership roles in group activities (Kahle 1985, Jones and Wheatly 1989, 1990, Jones 1989, Kahle et al. 1991, American Association of University Women 1992, Sadker and Sadker 1994, Roth 1996, Jovanovic and Dreves 1998). Girls have fewer opportunities to experiment, handle less science equipment, and participate less in science-related activities (Kahle 1985, Jones 1989, Jones and Wheatly 1990, Kahle et al. 1991, American Association of University Women 1992, Sadker and Sadker 1994). As a consequence, boys consistently report more classroom and extra-curricular science activities than do girls (Kahle and Rennie 1993, Jovanovic and Dreves 1998). The discrepancies in the quantity and quality of boys' and girls' science-related experiences are believed to account for the differences in their attitudes toward science and science-related careers (Jones 1989, Jones and Wheatly 1990, Kahle et al. 1991, American Association of University Women 1992, Kahle and Rennie 1993, Catsambis 1995, Jovanovic and Dreves 1998).

Boys' and girls' differential attitudes toward science are also reflected in their achievement in science. A strong correlation between attitude toward and achievement in science has been identified in various studies (Schibeci and Riley 1986, Bruschi and Anderson 1994, Weinburgh 1995). A meta-analysis of the research conducted between 1970 and 1991 indicates that 'in all cases a positive attitude results in higher achievement' (Weinburgh 1995: 387). Attitudes toward science also predict student selection of future science courses (Farenga and Joyce 1998) and affect students' aspirations to science careers (Catsambis 1995).

Female attrition from undergraduate science programmes appears to be due, in part, to the environment experienced by young women in their science classes (Hall and Sandler 1982, Sandler 1986, Gilbert and Pomfret 1995). In a landmark study, Hall and Sandler (1982) uncovered some of the overt and covert ways in which faculty and peers contributed to a climate that was 'chilly' for women students. A subsequent study by Sandler (1986) reported similar findings to those identified in 1982. In a more recent study, Meinholdt and Murray (1999) concluded that, instead of blatant sexism, today's women students experience exclusion or 'a null environment' in which women are simply ignored or excluded (p. 248).

Research on the attrition of women students from graduate science programmes indicates that the 'chilly climate' uncovered by Hall and Sandler (1982) in undergraduate classrooms might also play a role in the attrition of women from graduate science programmes (Hollenshead, Younce and Wenzel 1994, Dresselhaus, Franz and Clark 1995, Bauer and Green 1996, Golde 1996, 1998, Nerad and Miller 1996, Hirt and Muffo 1998). In a study by Bauer and Green (1996), over 60% of the women reported experiencing some form of harassment, and over 70% reported that their gender played a role on how they were treated. Others have uncovered subtle forms of discrimination such as advisors discussing science with men and social issues with women, or excluding women from collegial networking (Dresselhaus et al. 1995, Scholer 1998, Davis 1999). Seagram, Gould and Pyke (1998) posit that the attrition women from graduate science programmes may be the result of 'accumulated microinequities' that women experience as graduate students (p. 320).

Some researchers contend that many of the issues faced by graduate women in science are related to lack of a *critical mass* of women students and professors (Dresselhaus et al. 1995, Meinholdt and Murray 1999). 'Critical mass' is defined as 'the discrete point at which the presence of a sufficient number brings about qualitative improvement in conditions and accelerates the dynamics of change' (Etzkowitz, Kemelgor, Neuschatz, Uzzi and Alonzo 1994, p. 51). In a study comprising 17 physics departments, the researchers found a direct relationship between the quality of the climate and the proportion of women faculty and students (Dresselhaus et al. 1995).

Although some of the literature reviewed here points to the role that context plays on the gender gap in science and engineering, little is known about the role that discipline or department characteristics play on the differential attrition rate of men and women students from graduate science programmes. Even though women have made significant gains in accessing scientific knowledge, they continue to be a minority in many areas of science (National Opinion Research Center 2000). Furthermore, the Ph.D. thesis in science is primarily an apprenticeship in research during which students spend large periods of time in a laboratory sharing space and equipment with colleagues and research advisor (Widnall 1988, Holloway 1993, Conefrey 2000). According to Conefrey (2000), 'participating in a laboratory is crucial to succeeding in science because it socializes novice scientists into what is valued by their laboratory and by the larger community of scientists to which they aspire to belong' (p. 253). Thus, it is necessary to examine the extent to which context factors, such as the working environment in the research lab, affect graduate student attrition, particularly of women. Golde (1998) asserts that, 'to understand doctoral-student attrition, we must critically examine the role of discipline and programme in shaping student experiences' (p. 55).

Purpose

The study reported here focuses on the role that context factors (e.g. the environment in the research laboratory as shaped by colleagues and research advisor) play in the differential attrition rate of men and women graduate students in two science departments at a large research university. According to Bruner (1986), 'the images and narratives in a culture provide a map of possible roles and possible worlds in which action, thought, and self-definition are permissible (or desirable)' (p. 34).

Methodology

Setting

The study takes place in two graduate science departments, biology and chemistry, at a large research university in the Mid-West. The biology department offers doctoral and Master's degrees in seven areas of biology from molecular biology to ecology. The chemistry department offers only Ph.D.s in all the major areas of chemistry, from biochemistry to physical chemistry. However, students who decide to leave before completing their Ph.D. are given a Master's Degree if their work is deemed of sufficing quality. The student's research advisor controls this decision.

In both departments the doctoral programme is primarily based on research. Incoming graduate students are funded for a period of 5 years in the form of teaching and/or research fellowships. Students usually teach the first year and receive research assistantships after they join a research laboratory.

At the time of the study the biology department had 177 graduate students, 43% women. Of the 48 tenure-track faculty members, nine were women at various rank levels (two of assistant, five of associate and two of full professor). The chemistry department had 34 faculty members, none of them women, and 74% of them at the rank of full professor. Of the 186 graduate students in the chemistry department, 30% were women.

Sample

Results are based on survey responses from 170 graduate students (71 women and 99 men) and semi-structured interviews with 32 students (16 women and 16 men). Six of the students interviewed (five women and one man) had left the programme before completing their degree. The selection of students for the interviews was done to insure a representative sample in relation to gender, department, self-confidence level, and intention to leave the programme (LeCompte and Preissle 1993). Twelve faculty members, six from chemistry (all men) and six from biology (four men and two women), were also interviewed. A representative sample of faculty members in each department was selected using rank, age, area of specialization and gender (only in biology).

Data

Three sources of data are used in this study: (1) a five-point Likert-type scale survey questionnaire, (2) semi-structured interviews, and (3) departmental records. The data on faculty and student composition of each department, student undergraduate and graduate GPAs (grade point averages), and the student attrition rate (men and women), over a 9-year period, are based on departmental records. Students' perspectives on their work environment, as shaped by their colleagues and research advisor, are based on 24 items on the survey and semi-structured interviews.

Thirteen of the items on the survey were used to assess students' perceptions of the level of collaboration and collegiality among the students (men and women) in their research laboratory. Sample items are 'In my lab there is a lot of collaboration between my female and male colleagues' and 'I feel welcome to ask for help from my female/male colleagues' (see table 3 later for the complete set of items). Eleven additional items attempted to assess students' perception of their advisor's support and of any gender differences in the advisor's treatment of her/his students. Sample items include 'My advisor is often available for advice and/or support' and 'My advisor has equal expectations for her/his female and male students'. Another item, 'The level of mentoring in my department is very high', was used to assess students' perception of the level of mentoring in their department (see table 4 later for the complete set of items). Responses to the items on the survey were on a 1 (Strongly Disagree) to 5 (Strongly Agree) scale, with a midpoint defined as 'Undecided.' Each survey item included space for student comments. The alpha reliability coefficient for the 24 items on the survey was 0.84.

Demographic items in the survey included students' department, major, gender, age, ethnicity, and marital status. Students were also asked to report the average number of hours (per week) that they spent conducting research in the laboratory, and to rate their self-confidence level at two points in their programme: when entering graduate school, and at the time of the study. The scale for self-confidence ranged from 1 (Very Low) to 5 (Very High), with a midpoint defined as 'Moderate.'

The semi-structured interviews were conducted after the surveys had been returned and were used to explore, more in-depth, some of the issues uncovered in the survey, including possible reasons for student attrition. Thus, while the survey helped to provide breadth to the study and allowed for statistical comparisons by gender in each department, the interviews provided 'an occasion for depth probes

– for getting to the bottom of things . . .' (Glesne and Peshkin 1992: 85). Each interview was audiotaped and took between 30 and 60 minutes.

Analyses

Chi-square tests were used to determine significant gender differences in the student attrition rate in each department. Significant gender differences, in each department, on students' undergraduate and graduate GPAs, the weekly number of hours spent in the laboratory conducting research, and self-confidence level when entering graduate school and at the time of the study were determined using independent sample t tests. Multiple analysis of variance was used to identify significant gender differences in each department on student responses to the survey items and to find department and gender interactions on each item. An alpha level of 0.05 was used for all statistical tests.

The transcripts of the students' comments to the items on the survey and of their answers to the interview questions were analysed using the techniques of naturalistic inquiry (Lincoln and Guba 1985, Miles and Huberman 1994). After the interview, tapes were transcribed verbatim and students' comments to the survey questions copied – a text-based coding was used (Miles and Huberman 1994). As each transcript was read several times, one-word or two-word codes were attached to each segment of the data. After all transcripts were coded in this manner, similar codes were grouped together and organized into broader themes. The accuracy of the themes was accomplished through member checking and a peer reviewer (Lincoln and Guba 1985).

Findings

Student background characteristics

Analyses of the data did not uncover significant gender differences in students' incoming self-confidence, graduate GPA, and the weekly number of hours conducting research in the laboratory (see table 1). However, significant gender differences were found in the biology department in the students' undergraduate GPA. Men entered graduate school with a significantly lower GPA than the women [t (65) = 2.49, p = 0.02]. Table 1 shows that both groups of men and women entered graduate school with similar self-confidence levels. However, at the time of the study the women in each department reported a significantly lower self-confidence level than did the men (see table 1). This difference was greater in chemistry [t (83) = −2.63, p = 0.01] than in biology [t (84) = −2.05, p = 0.04].

Student attrition rate

Statistical analysis of the data uncovered significant gender differences in the graduate student attrition rate in each department (see table 2). In the biology department the attrition rate of women, for each entering cohort over a 9-year period, averaged 31%, while the attrition rate of men for the same time period averaged 16% [χ^2 (1, n = 293) = 9.06, p = 0.003]. In the chemistry department, these figures were 45% for women and 30% for men [χ^2 (1, n = 433) = 8.90, p = 0.003]. Even though

Table 1. Student characteristics: undergraduate and graduate GPA, weekly hours spent in the laboratory, and entering and present self-confidence levels.

	Biology department		*Chemistry department*	
Characteristic	*Females*	*Males*	*Females*	*Males*
Undergraduate GPA	3.60*	3.39*	3.55	3.53
Graduate GPA	3.74	3.70	3.62	3.64
Weekly hours in lab	43.44	46.72	48.90	50.79
Entering self-confidence	3.98	3.91	4.00	4.00
Self-confidence at time of study	3.33*	3.76*	3.16**	3.70**

*$p < 0.05$, **$p < 0.01$.

Table 2. Student attrition rate in each department for each entering cohort 1986–1994.

	Biology department				*Chemistry Department*			
	Females		*Males*		*Females*		*Males*	
Cohort year	*Entered*	*Left (%)*	*Entered*	*Left (%)*	*Entered*	*Left (%)*	*Entered*	*Left (%)*
1986	10	4 (40)	23	6 (26)	15	2 (13)	33	9 (27)
1987	10	1 (10)	12	3 (25)	17	9 (53)	27	9 (33)
1988	19	6 (32)	14	3 (21)	19	9 (47)	33	10 (30)
1989	11	2 (18)	21	3 (14)	13	7 (54)	23	8 (35)
1990	13	7 (54)	19	6 (32)	17	9 (53)	33	10 (30)
1991	11	1 (9)	21	2 (10)	24	8 (33)	28	11 (39)
1992	25	12 (48)	29	2 (7)	16	8 (50)	35	12 (34)
1993	16	3 (19)	13	1 (8)	17	11 (65)	24	10 (42)
1994	13	4 (31)	13	1 (8)	17	6 (35)	42	5 (12)
Avg	15	4 (31)**	18	3 (16)**	17	8 (45)**	31	9 (30)**

**$p < 0.01$.

gender differences in the student attrition rate were similar in both departments, the overall student attrition rate (of men and women) in chemistry was significantly higher than in biology [χ^2 $(1, n = 726) = 12.86, p = 0.000$].

The student attrition rate was determined by counting any student, who had left from each cohort, without a degree or with a degree different from the one originally sought. Students who were accepted to the Ph.D. programme but later changed to a Master's Degree were included in the computation of the attrition rate. This method is consistent with the literature (OSEP 1996, NSF 1998). The NSF defines graduate student attrition as 'the proportion of the entering cohort into a doctoral degree programme that does not complete the graduate programme undertaken' (1998: 3).

Context factors related to student attrition

Studies on graduate student retention indicate that the social climate plays an important role in graduate student success (Hollenshead et al. 1994, Dresselhaus et al. 1995, Bauer and Green 1996, Curtin et al. 1997, NSF 1998, Conefrey 2000, Rosser and Zieseniss 2000). Because of the large number of hours spent in the research laboratory, the social climate for the students in this study was shaped, mainly, by their relationship with colleagues and advisor. Research indicates that colleagues and advisor are key agents in the socialization of new graduate students into a discipline (Girves and Wemmerus 1988, Baird 1992, Lovitts 1996). According to Girves and Wemmerus, 'The frequency and quality of student/faculty interactions appear to be important predictors of retention for men, whereas both student/faculty and peer interactions are important predictors of retention for women' (1988: 164).

Two sections in the survey questionnaire were used to assess students' perceptions of the social climate in the research laboratory, as shaped by students' relationship with their colleagues and advisor. Results from the survey combined with student responses from the interviews are presented in the following sections.

Student relationship with colleagues

Thirteen items in the survey were used to examine the quality of the students' relationship with their colleagues, both female and male. These items examined, in various ways, the level of collegiality that existed among the members of the research laboratory. Analysis of the data found significant gender differences only in the chemistry department. As results in table 3 indicate, the women in chemistry were less likely to agree that their comments were taken seriously by their male or female colleagues (statements 3a and 3b), that their male colleagues asked for their opinion or help (statement 4a), that they felt welcome to ask for help from their male colleagues (statement 5b), that they often discussed science with their male colleagues (statement 6b), and that they often socialized with their male colleagues (statement 7b).

These findings parallel the results of other studies (Hollenshead et al. 1994, Curtin et al. 1997). The women in the study of Curtin et al. were less likely to agree that other graduate students readily discussed ideas with them, respected their opinions, valued them as individuals, or treated them as colleagues. Table 3 also shows significant department/gender interactions for three of the items indicating that gender differences in these items are dependent on department.

Collegiality. Student comments during the interviews reflected the results of the survey. While most students in biology remarked that in their department the 'emphasis is on cooperation/collaboration with other people', many of the students in chemistry commented that in their department 'each group does their own thing. There are no interdepartmental collaborations at all' or, as one of the women students put it, 'You will be pretty much on your own'. Another woman reported that 'intra-lab politics make it difficult to work in [her] research group', while one of the men described the environment in his laboratory as a 'cut throat atmosphere'. In fact, results indicate that each research laboratory in the chemistry department

Table 3. Gender differences in students' perception of their relationship with colleagues and department/gender interaction.

	Biology department		*Chemistry department*		*Interaction*
Statement	*Females, Mean*	*Males, Mean*	*Females, Mean*	*Males, Mean*	*Depart* gender, F*
1. In my laboratory there is a lot of collaboration between my male and female colleagues	4.15	4.36	4.00	4.27	0.03
2a. My male colleagues listen well to women	4.06	4.25	3.67	4.11	0.69
2b. My female colleagues listen well to men	4.18	4.14	4.23	4.11	0.19
3a. I often feel my comments/ ideas are taken seriously by my male colleagues	4.27	4.17	3.74**	4.34**	8.08**
3b. I often feel my comments/ ideas are taken seriously by my female colleagues	4.41	4.19	4.00*	4.34*	6.55*
4a. My male colleagues often ask for my opinion and/or help	3.85	4.06	3.59*	4.11*	1.09
4b. My female colleagues often ask for my opinion and/or help	4.26	4.06	4.04	3.93	0.13
5a. I often feel welcome to ask for help from my female colleagues	4.41	4.33	4.30	4.41	0.59
5b. I often feel welcome to ask for hep from my male colleagues.	4.21	4.28	3.93**	4.50**	3.62
6a. I often discuss science with my female colleagues	4.35	4.06	4.00	4.23	2.70
6b. I often discuss science with my male colleagues	4.09	4.11	3.93**	4.48**	3.17
7a. I often socialize with my female colleagues	4.15	3.58	4.04	4.07	2.49
7b. I often socialize with my male colleagues	3.74	3.94	3.41**	4.36**	4.11*

$^{*}p < 0.05$, $^{**}p < 0.01$.

was a separate entity with its own cultural norms or, as one of the women students described it, 'each lab is very much a little island'.

The small number of women in most laboratories had little impact on the culture of the individual laboratories and on the department as a whole. The women felt as outsiders in a culture governed by masculine patterns of behaviour. While discussing the social climate in her laboratory one of the women stated that, 'there are definitely times when you feel very awkward and very out of place'. According to her, 'It gets pretty crude sometimes, their whole talk [male colleagues]. If you sit in the lunchroom 90% of their talk is sports and crude jokes'. Another woman student commented that, 'The men in the lab don't really think of me as a peer' because 'they talk to each other about science, and then they ask me where something is'. Yet another woman remarked on how she 'never felt really welcome to the lab in general. When I ask a male colleague for help, I feel like I'm intruding on something'.

In some of the laboratories, the senior graduate students played an important role in the socialization of incoming graduate students. However, as the following quote illustrates, instead of contributing to her socialization into a community of practice (Davis 1999, Conefrey 2000), this woman's peers used their power to limit her access to membership in that community (Lave and Wenger 1991 in Davis 1999):

> Here I am a first year graduate student working with a$500,000.00 instrument and I think something is wrong, and it's not something I did but something someone else who used it before me did. I go to this person, and not having a lot of knowledge because I'm a first year graduate student, I say: 'I really think something is wrong with this, the results of this experiment are not quite what I expected.' Then that person responds: 'well, what *did you do*?' and everyone else says kind of laughing: 'what did *you* do? Did *you* break it?' So that was really bad, I think that can really blow away a woman's self-confidence. I was afraid to break anything; I was afraid to make a mistake; I was afraid for any of these guys to sense any bit of fear or uncertainty I had. I was a nervous wreck all the time and I dreaded the lab.

Sandler (1986) contends that issues related to the climate faced by graduate women are especially problematic because they occur at a time of transition between student and professional. During this stage of their education, women students are being socialized into a chosen field. This socialization involves close and informal work relationships with peers and advisors as well as competition for access to scarce resources. According to Sandler, at this level graduate men view graduate women as potential colleagues and competitors.

Student relationship with advisor

According to Tinto (1993) the graduate education process progresses in three stages: (1) transition to the programme, (2) acquisition of skills, and (3) the conduction of research. Graduate student persistence in the third stage is primarily the result of the student relationship with the advisor (Tinto 1993). This assertion is supported by research on graduate student success (Jacks, Chubin, Porter and Connolly 1983, Girves and Wemmerus 1988, Hollenshead et al. 1994, Golde 1996, 1998, Davis 1999). Successful scientists, especially women, consistently report on the important role that their advisors played in their careers (Jacks et al. 1983, Sonnert and Holton 1996, Davis 1999).

Given the impact that advisors have on graduate student success, 10 items in the survey examined students' perception of the relationship with their advisor. Another item (statement 8 in table 4) examined the level of mentoring in each department. Research on mentoring indicates that students who have a mentoring relationship with their advisors feel professionally affirmed and are more productive after graduation (Heinrich 1991, Subotnik and Arnold 1995).

Once again no significant gender differences where identified in the biology department on the items examining students' perception of the relationship with their advisor. However, in the chemistry department significant gender differences

Table 4. Gender differences in students' perception of their relationship with advisor and department/gender interaction.

Statement	*Biology department*		*Chemistry department*		*Interaction*
	Females, Mean	*Males, Mean*	*Females, Mean*	*Males, Mean*	*Depart* gender, F*
1. My advisor has equal expectations for his/her male and female students	4.09	4.00	3.44	3.89	1.79
2. I often feel my comments/ ideas are taken seriously by my advisor	4.01	4.31	3.70	4.12	.62
3. My advisor is often available for advice and/or support	4.09	4.11	3.67	4.18	1.79
4. I have learned a lot from my advisor	4.00	4.36	3.89**	4.5**	.64
5a. I feel my advisor has the same expectations for me as for my female colleagues	4.26	3.94	3.82	3.91	1.36
5b. I feel my advisor has the same expectations for me as for my male colleagues	4.15	4.25	3.44**	4.18**	3.80
6a. My advisor asks for the opinion of his/her female students even when there are male students around	4.18	4.11	3.44*	4.07*	3.76
6b. My advisor asks for the opinion of his/her male students even when there are female students around	4.5	4.08	4.19	4.20	2.52
7a. My advisor knows how to deal well with his/her male students	3.89	3.78	3.85	4.02	.68
7b. My advisor knows how to deal well with his/her female students	3.50	3.72	3.15*	3.68*	.66
8. The level of mentoring in my department is very high	3.44	3.33	2.48**	3.59**	9.66**

*$p < 0.05$, **$p < 0.01$.

were found in a number of items. As results in table 4 indicate, the women in chemistry were less likely to agree that that they had learned a lot from their advisor (statement 4), that their advisor had the same expectations for them as for their male colleagues (statement 5b), that their advisor asked for the opinion of his female students even when male students were present (statement 6a), and that their advisor knew how to deal well with his female students (statement 7b). The women in chemistry were also much less likely to agree that the level of mentoring in their department was very high (statement 8). This item also exhibited significant department/gender interaction, indicating that the gender difference is dependent on department.

Advisor support: biology. Student comments during the interviews also indicate that students' relationship with their advisor differed considerably in the two departments. Students in biology often described their advisors (and other faculty) as 'very approachable'. For example, one of the graduate women commented that 'I can go to anybody and talk to them about what I'm doing and if I have a question about something I've never been turned away'. Another woman reported that '[her] advisor is a great guy! As well as being a very bright man, he knows that grad students have interests outside of science'. The men in biology made similar remarks. One of them described his advisor as 'open to discussion and very supportive'. Another one credited the collaborative atmosphere in his laboratory to his advisor's 'ability to treat all students (men and women) equally and fairly'.

Competition and aggressiveness: chemistry. In the chemistry department, however, student comments focused primarily on the high work expectations that their advisors imposed on the members of the research laboratory. Students frequently mentioned the need for 'working hard' and for being 'self motivated'. According to these students, the high work demands led to an atmosphere that was 'incredibly uptight and competitive'. One of the men in chemistry described the social climate in his laboratory as 'a highly competitive environment where you are constantly asked to prove yourself. The prevailing attitude is; at all costs produce results and impress your advisor'.

The women in chemistry were also aware of the high working expectations and the need to be 'aggressive'. According to one them, 'If you want to succeed in our group you *must* be aggressive and solicit help from other group members and mostly from advisor'. She added that 'aggressive group members who seek out our advisor for talks about research (or anything) get better treatment from advisor'. Another woman reported that 'in our group competitiveness comes where you do what it takes to get ahead without regard for other people'. This, according to her, might include 'you needing a piece of equipment and going ahead and taking it, and if someone is using it "too bad" '; or 'you talking to someone about your ideas and the next thing you know they have gone to your advisor with them and it's all of a sudden their idea'. Another woman described the mentoring style of her advisor as based on a Social Darwinist approach – 'survival of the fittest'.

Albeit the recognition of the need to be aggressive, many of the graduate women appeared to have difficulty meeting the needed degree of competitiveness and aggressiveness to succeed. According to some of them, they had been told they 'weren't aggressive enough'. Some researchers contend that the socialization of youngsters into gender-specific roles does little to prepare females for the competitive environment that characterizes many scientific fields (Sadker and Sadker 1994, Roth 1996, Jovanovic and Dreves 1998). Researchers have found that women tend to 'shy away from very competitive projects more than their male counterparts' (Sonnert and Holton 1996: 68). According to Holloway (1993), '[Women] respond to a challenge better if the process of meeting it is framed as a collaboration rather than a competition' (p. 99). A number of the graduate women in chemistry did voice their preference for collaboration over competition. 'I prefer working in a team and discovering new things', replied one. Another one added that, although she preferred to work in collaborations, 'it's not how you get your degree'.

Null environment. Meinholdt and Murray (1999) contend that the blatant sexism that existed in science has been substituted by a 'null environment' characterized by the exclusion of women from informal interactions with peers and professors. Yet, according to Girves and Wemmerus (1988), 'being treated as a junior colleague by the adviser accounts for much of the variability in degree progress' (p. 185). Students, particularly women, who receive high levels of support from their advisors are more likely to succeed in graduate school and persist to complete their degrees (Kluever 1995, Lenz 1995). In the chemistry department the lack of collegiality in most laboratories, and in the department as a whole, combined with the lack of support from their advisor, appeared to be contributing to a 'null environment' for many of the graduate women, as illustrated in the following quote:

> I worked on a project by myself and I worked so hard to try to learn and understand everything. I would force my advisor to say hello to me in the hall, and he would barely do that. But right after that he would stop and talk to someone else, a guy, about drinking or skiing.

Another woman commented that she had 'received minimal feedback and support from [her] advisor'. She added that 'of the over 40 Ph.D's granted by the advisor in the past 25 years, only 4 have gone to women (and many more than 4 have tried)'.

These findings are not uncommon in studies involving women scientists and students. Other researchers have also uncovered subtle and overt ways that have limited women's participation in science (Holloway 1993, Bauer and Green 1996, Sonnert and Holton 1996, Scholer 1998). In these studies, women scientists and students report subtle forms of discrimination such as advisors discussing science with men and social issues with women, or excluding women from collegial networkings (Holloway 1993, Sonnert and Holton 1996, Scholer 1998).

Thus, in the chemistry department, advisors played a large role in the kind of work environment that existed in their laboratories, and in the department as a whole. Indeed, one might argue that these advisors were the gatekeepers to their students' success, especially women's (Dresselhaus et al. 1995, OSEP 1996, Golde 1998, Davis 1999). The five students interviewed for this study, who had left before completing their degree, attributed their leaving to issues with their advisor. These findings support the results of other studies in which problems with advisors are often the most cited reasons for leaving graduate school (Nerad and Miller 1996, OSEP 1996).

Sense of isolation. Although research indicates that a mentor or role model does not necessarily need to be of the same race or sex as the protégé, seeing others of the same sex and/or race in positions of power and expertise helps affirm one's career aspirations (Astin and Astin 1993, Kegel-Flom 1995, Janes 1997). In the chemistry department, the lack of women faculty who could serve as role models and mentors added to the sense of isolation that many graduate women experienced. According to one of them, 'there is no one to look up to'. Another one commented that 'It would help if we had at least one woman professor because that makes you think, "what's wrong? Is there something going on here" '?

The large number of women students who left before completing their degree also contributed to a feeling of isolation and helplessness among those who stayed. One of the women reported that 'all around me women are leaving with their

Master's Degree. And they are all my friends, and I see what they're going through, and it's very discouraging'. Another one commented on how the men 'see other guys who are happy, are going on, and are joining the group', while she saw 'women who were leaving'. This in turn led to 'a panic in your mind because, you say, "well, I know I am good enough, but [name withheld] is not sitting here anymore" '.

Men's awareness of gender issues: chemistry. Some of the men in the chemistry department were also aware of the inhospitable working environment that many of their women colleagues experienced in certain laboratories, and in the department as a whole. They commented on specific laboratories known for the negative working environment that advisors had created and where women had few chances of succeeding. One of the men who had left the programme described one such advisor:

> I knew at least another professor who was terrible. He created a terrible environment for both men and women students in the laboratory, but particularly for women, though he did not do it in an obvious manner. No woman had ever gotten a Ph.D. under him. He had a huge ego, although he had a good scientific mind. A friend of mine decided to leave before finishing. She hated him. I wasn't his student, but he even had a negative impact on me.

Another one commented on the negative impact that the lack of women in faculty might have on his women colleagues:

> I don't think this department is encouraging to women at all. It's the only department that I know of in chemistry that has 34 faculty members and not one of them is a woman. So if you are a woman in a field like chemistry, which tends to be pretty competitive as far as research (even with other groups) and in an environment that it's essentially male-dominated with no real role models, it's going to be really discouraging.

When asked why so many graduate women left from the chemistry department another of the graduate men responded:

> I can't believe it's due to some sort of intellectual inferiority. There were probably thirteen graduate students in my subdiscipline when I came, half of them were women. I think two of them got Master's degrees and most left before or after their candidacy exams. All the women graduate students left before getting their Ph.D. I think it has to do with the fact that several of those students went to work in very large male dominated groups. I'm left with the conclusion that somehow the environment isn't friendly to women.

Thus, in the chemistry department the lack of collaboration and focus on competition, combined with lack of support from their advisors, and the absence of women faculty who could serve as role models and mentors, led to the erosion of many women students' confidence as indicated by the large drop in their self-confidence during graduate school. Furthermore, the high attrition rate of graduate women in this department indicates that many of them opted to leave. According to one of the more senior graduate women:

> Most of the [women students] quit because it's just not worth to go through what they have to go through. They are young and totally stunned by what they are experiencing and they just want to get the hell out. Most of them do not realize how sexist the environment is and they don't have the skills to fight back. They don't want to become the kind of person they feel they would have to become in order to get through.

Gender issues in the biology department

As indicated in tables 3 and 4, analysis of the survey data did not uncover significant gender differences in students' relationship with colleagues and advisor. Furthermore, the great majority of the students interviewed in the biology department spoke very positively about their working environment. Yet, in this department the attrition rate of graduate women was significantly larger than that of graduate men (see table 2). Thus, the interviews were used to explore the reasons that might be causing a substantive number of graduate women to leave before completing their degree. Two major themes were identified in the data: the conflict between a career in science and a family (role conflict), and the schism between teaching and research.

Role conflict. Research indicates that balancing the time demands between a scientific career and a family is one of the most often cited constraints by women and by some men scientists (Brennan 1996, Curtin et al. 1997, Scholer 1998). According to Brennan (1996), many women, and to some extent men scientists, choose not to pursue a research career in science because of the constraints that such a career puts on people's lives. The comments from some of the graduate women in biology support Brennan's contention that 'as graduate students they realized they could not live the way their advisor lived – the hours at work, the pressures, and the toll on family life' (1996: 10). As one of the women students pointed out, 'at this university professors (men and women) don't really have lives. They are sort of programmed research machines'.

Some of the women students in biology believed the culture of science was not supportive of families. As one of them pointed out, 'There's definitely the myth, and that definitely comes from the culture of science, that you have to do this and you can't have a life if you're serious'. Another one stated that, 'most women I see in the field, who are successful by the traditional indicators, don't have children'. Yet another one added: 'at a major research institution having a family seems incompatible with achieving tenure'.

The heightened perception in the biology department of the conflict between a career in science and having a family appeared to be the result of the greater visibility of this issue in the department. A greater percentage of the graduate women in this department were married (38%), and some of them had children. As one of them pointed out, 'I am having a lot of trouble trying to fit both a family and a career'. In addition, 19% of the faculty members were women and most of them were married with young children, and many of the men on the faculty were also trying to balance dual careers and young children.

Research versus teaching. In the biology department students were being trained, primarily, for a research career in academia, similar to that of their advisors. Teaching, according to the students, 'was not taught or valued' and 'the way you are rewarded in the department is not having to teach. That's the way they tell you they like you, when they take away your course load'. In fact, students spoke of a 'deep divide between people who are teachers and those who are researchers'. Yet, students (particularly the women) who faced a possible conflict between a career in science and having a family viewed a teaching career in a 4-year college as a possible solution to this conflict. However, the low status (and support) that teaching received in the biology department left students few options.

In the chemistry department a number of factors contributed to students' lack of awareness, and concern, for the conflict between a career in science and having a family. The lack of women on the faculty and the seniority status of most of the men on the faculty contributed to the low visibility of such issue in the department. Students in chemistry also tended to be younger, and fewer women were married. Furthermore, the chemistry department had close ties to industry and it was acceptable (and expected) that many of the students in chemistry would secure jobs in industry. Thus, students interested in having a career in science and a family, or who did not want to experience the pressures related to tenure in academia, opted for jobs in industry. Although some of the graduate women in biology were aware that women in industry 'are able to have families and still do interesting science', the lack of collaboration between their department and industry made such option seem unfeasible.

Conclusions and implications

According to the authors of a report from the NSF, 'Persons who are accepted for advanced degrees presumably have demonstrated the potential to perform in these areas' (NSF 1998: 2). The results of this study support this contention. Analyses of the data indicate that both men and women students in each department entered their graduate programme with high undergraduate grade-point average and self-confidence. Yet a large percentage of them, women in particular, did not complete their degree. Indeed, the group of students (the men in biology) who entered graduate school with the lowest grade-point average and self-confidence fared better than the other three groups, as indicated by their lower attrition rate. These findings support Lovitts' contention that '[graduate student] attrition has less to do with what the student brings to the university than with what happens to the student after s/he has been admitted' (1996: 3).

The results of this study show that the reasons for the significantly larger attrition rate of graduate women differed in the two departments, and were related to department and discipline contexts. In the chemistry department, the large attrition of graduate women appeared to be related to issues resulting from lack of a 'critical mass' of women professors and students (Dresselhaus et al. 1995, Meinholdt and Murray 1999). As previously pointed out, the chemistry department did not have women on the faculty. Even though 30% of the students were women, their subordinate status gave them little or no power to affect the culture of the research laboratory and of the department. In fact, the senior professors, 74% of them at the rank of full professor, controlled the culture of the chemistry department. Students spoke of junior professors (all men) who were denied tenure because 'supposedly they didn't tow the line'. According to one of the graduate men, 'they want people who are like them'.

As a result, the culture of the chemistry department was based on traditional male cultural norms of individualistic competition and aggressiveness (Holloway 1993, Eisenhart 1994, Gilbert and Pomfret 1995, Subramaniam and Wyer 1998, Conefrey 2000). Students who could adjust to this competitive environment succeeded, while those who were unable to do so left. Although the attrition rate of graduate men was considerable, the environment in the chemistry department had a greater negative impact on the women students, as indicated by their larger drop in self-confidence and attrition rate. This competition-driven environment, combined with lack of women faculty who could serve as role models and mentors, and the large number of women students who left from each entering cohort, had a demoralizing effect on those women who stayed.

Changes in the chemistry department, therefore, are most needed at the department level. However, it is unlikely that significant changes will occur in the department until a large number of senior faculty members retire. Change will only occur when a significant number of new faculty members, men and women, reach positions of power in the department, and instill new norms of success that are based on collaboration and collegiality. As Jacks et al. (1983) point out, 'Formal training is only as effective as the informal support system that faculty and peers provide' (p. 81).

In the biology department, even though women had achieved a critical mass, their increased presence seemed to heighten the perception of the role conflict that existed between trying to balance a career in science and a family. According to Eisenhart (1994), 'Men and women who are trying to coordinate work and family are experiencing the effects of trying to bring culturally female characteristics into the workplace' (p. 193). As Etzkowitz et al. point out, 'A modest increase in the number of women in science, without a change in the structure of the scientific workplace, creates a paradox of critical mass' (1994: 51).

The lack of alternative options for the graduate women who perceived this conflict might have contributed to their eventual decision to leave. Conversations with faculty members in the biology department suggest that faculty and department administrators were aware of this issue. The administration had implemented a number of changes to help faculty better balance career and family demands. For example, junior faculty (men and women) with a newborn could opt to stop their tenure clock for 1 year. A few of the faculty members shared dual appointments with their spouses, and junior faculty members often mentioned the administration's willingness to accommodate their family's demands. However, conversations with the students indicate that few of them were aware of these innovations. Students' awareness of the conflict between a career in science and a family was based on the perception that the effort needed to balance both was excessive, as illustrated in the following quote from one of the women professors in the biology department:

> It seems to me like now we should be serving as role models for young women who can look at us and say, 'you are trying to do it all and so can I; I can have a career and a family'. But most of the young women I talk to here are coming to me with the opposite response. They are saying, 'I don't want your position because it looks too hard and too stressful, and I see you have no time for anything else'.

Thus, in the biology department, changes will have to focus on developing alternative options for those students who might be considering a career in science other than research in academia. These changes might include closer collaborations with industry and an alternative doctoral track that combines research and pedagogy. At the time of the study, students did not believe they had any alternative options.

A number of recent publications have voiced the need for studies that examine the impact of department characteristics on graduate student attrition (Golde 1996 1998, OSEP 1996, Hirt and Muffo 1998, NSF 1998). According to a report by the NSF, 'the graduate education experience is shaped by specific situations – the student's relationships with specific faculty, in some cases just one or two members of a department. Research designs, therefore, ideally should capture that complexity' (1998: 4). As the results of this study indicate, although both departments were part of the same institution, the contextual factors that shaped female attrition in each department were notably different. While in the chemistry department the working environment characterized by lack of collaboration, competition, and lack of advisor's support were the primary factors in the high attrition of graduate women, in the biology department graduate women's awareness of the conflict between a successful career in science and a family appeared to be the main factor in their decision to leave. Without the qualitative portion of the study, the complexity of issues that contributed to the larger attrition of graduate women in each department would not have been uncovered.

Limitations

A few words of caution regarding the results of this study are warranted. First, this study examined only two science departments, both in the same university. Second, as with any study that relies on the voluntary participation of respondents, the moderately low return rate on the survey (approximately 50%) limits the scope of the study. The analyses are also limited by the comparatively small sample of students (32) interviewed. Although an effort was made to gain a diversity of views by choosing to interview students with a variety of opinions, some important views might not have been included from those who were not interviewed. Third, the sample included only six students who had left the programme before completing their degree. A study including a larger number of quitters would help determine the extent to which the results of this study could be generalized to other students who had left the programme.

Results from the interviews also appear to indicate that student attrition, particularly of women in chemistry, was more widespread in certain discipline areas and/or laboratories. Although attrition records for each entering cohort were obtained from each department as a whole, attrition records from each research laboratory and discipline area would have helped identify specific areas of concern that contributed to the high student attrition rate, especially females. These data, combined with extended periods of observations in each department's various laboratories, would have helped identify additional contextual issues and add reliability to the findings presented here. Unfortunately, at the time of this study the researcher was unable to obtain access to these data.

The results of this study therefore reflect only the perceptions of the participants and should not be generalized to science departments in other universities. Although the accounts of the students in this study might be similar to those in other departments and universities, only the reader, who might have more extensive knowledge of the environment in other science departments, can determine the extent to which the findings presented here apply to other settings.

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