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ABSTRACT

This project explored university science students' career and educational plans and looked for causes of defection from science, with particular interest in possible sources of gender difference in defection rates. A survey of 164 Canadian undergraduate students in mathematics and basic sciences found that: (1) over three fourths of the students intended to stay in mathematics or science; (2) gender differences in students' choice of field were not significant, though proportionately fewer of the women who rated themselves low in ability intended to remain in the field; (3) women rated themselves as more competent in nonscience subjects than men did; (4) an equal number of students planned to go directly to a job or to continue their education full-time; (5) the most frequently cited career motivation was self-fulfillment, followed by financial rewards and nonmaterial benefits; and (6) students' attributions for success did not differ by gender. Follow-up interviews conducted with 16 students addressed the topics of peer group relationships, teacher-student relationships, and reasons for program choice. The study concluded that, although males and females did not differ in their plans to remain in math/science, a number of factors were identified that may work together to produce a higher defection rate among women than among men, such as heavy workloads, differential perceptions of ability in nonscience fields, and social networks. (Contains 21 references.) (JDD)

Choosing Science

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The development of mathematical and scientific ability in young people concerns several communities. The interest among educators of the gifted is reflected in the number of programs that have been developed with this focus. The literatures on women and gifted girls also pays more attention to math/science fields, where women remain underrepresented, than to other disciplines (Callahan, 1991). And, in recent years, the scientific community has focussed on the need for increasing numbers of both males and females to enter the field in order to meet the demand for future scientists.

It is not enough to attract students to the field if they do not remain there, yet little attention has been paid to the problem of attrition. The greatest loss occurs in the transition to university (Hilton & Lee, 1988) but Green (1989) reported that more than 50% of students who initially enrol in math/science do not graduate from that field, and Nevitte, Gibbins, and Codding (1988) documented that many students who complete a first degree in science do not continue into science careers. The largest defection rate, 59%, was among women in mathematics and physical sciences.

This project explored university science students' career and educational plans and looked for causes of defection from science. Of particular interest were possible sources of gender difference in defection rates. Variables related to women's choice of mathematics and science courses or careers were addressed, including attributions for success and self-perceptions of ability in a science.

Quantitative Study

Method

Subjects. Questionnaires with postage-paid self-addressed envelopes were mailed to undergraduates students in mathematics and basic sciences at two universities in a large city in Eastern Canada. In all, 173 questionnaires were returned, representing a return rate of 29%. Responses from students whose main area of concentration was not in one of the above fields were eliminated, leaving 164 respondents. Incomplete responses further reduced the *n*'s in most analyses.

Subjects were not selected for giftedness. However, the universities' selection process ensured that all are academically able individuals relative to the general student population. All had succeeded in a relatively challenging junior college science program, or equivalent, in order to be eligible for a university program. Further indications of relatively high ability comes from their self-ratings for academic achievement in science and nonscience subjects. On a scale of 1 (low) to 7 (high), 72.5% rated themselves 6 or 7 in science achievement, and 80.4% rated themselves 6 or 7 in nonscience achievement.

There were more male than female respondents (Table 1) but the gender ratios did not differ by students' year, program, or university.

Insert Table 1 about here

Instruments. The questionnaire requested information about students' studies and gender. Three open-ended questions addressed students' career plans, issues they considered important in selecting a career, and their perceptions of causes of success in science and nonscience courses. Additionally, students were asked to rate themselves from 1 to 7 on science and nonscience achievement.

Results and Discussion

Career plans. The majority of students, 78.5%, intended to stay in mathematics or science (Table 2). Only 7.0% planned to leave the field on graduation, and

14.6% were undecided or gave unclear responses. These results contrast with earlier reports that more than 50% of students do not intend to stay in the field (Nevitte, Gibbins, & Codding; 1988). However, in that study students who intended to go into business were considered to be leaving science. Most students in this study who intended to enter business sought work in fields related to their undergraduate studies; consequently they were considered to be remaining in the field.

Insert Table 2 about here

An analysis was made of the effects on career plans of perceived academic performance in science. Students rated themselves from 1 (low) to 7 (high). Because few students rated themselves below 4, scores from 1 to 4 were recoded as "low" (28%), 5 and 6 became "average" (51%), and 7 was considered "high" (21%).

Ability had a significant effect on students' choice of field, $X^2 = 10.73$; df = 4; $p < .05$ (Table 2). Students who rated themselves average were most likely to plan to stay in science, while those who gave themselves a low rating were least likely to.

Gender differences in students' choice of field were not significant. However, when ability and gender were both considered there was a gender difference among those who intended to remain in science: Proportionately fewer of the women who gave themselves a low rating intended to remain in the field (Table 2).

Compared to females, males rated themselves lower on nonscience achievement. This suggests the possibility that low-ability women may be more willing than men to leave science because they have higher expectations of success in other fields.

<u>Education</u>. Responses to the question concerning students' plans to continue their education were coded into "further education", "job", "unsure", and "education plus". The latter category included students who planned to combine part-time study with work, or to work and then return to university. An equal number of students planned to go directly to a job or continue their education full time (Table 3).

Insert Table 3 about here

The gender difference in students' plans showed a trend toward a difference (Table 3). However, on further analysis only the differences in the job category reached significance, with more women than men intending to go directly to a job on graduation.

Self-ratings of science achievement had a significant effect on students' plans to continue their education without a break, $X^2 = 10.15$; df = 4; $p < .05$. High-ability students were more likely to plan to continue their education, and low ability students were more likely to plan to seek work. These effects were consistent for males and females. Contrary to Nevitte, Gibbins, and Codding (1988) high ability females and males did not differ in their educational plans.

Career Motivations. The number of responses to this question ranged from none to nine with a mean of 2.2. Eight categories of motives for seeking a particular type of work emerged. Self-fulfillment, mentioned 98 times, was the most frequently cited motivation. Financial rewards was second with 83 mentions and non-material benefits was third with 53 citations. Human considerations, which included both pleasant colleagues and family concerns, were a distant fourth with 29 people indicating it was a factor.

There was a trend towards a gender difference in the overall pattern of responses to the question concerning career motivation, $X^2 = 14.02$; df = 7; $p <$ .10. Females more frequently than males gave the response "help others" and males more frequently gave task-related challenges as a motive.

Attributions for Success. Interest and effort were the two most frequently reported reasons given for success in both science and nonscience courses, and ability was third. Students attributions for success did not differ by gender.

Qualitative Study

Method

A form asking students from one university to participate in follow-up interviews was included in the initial mailing. Interviews were carried out with nine females and seven males. Eight informants were in their final year of a three year program. Four each were in their first or second year. A range of fields were represented: five from physics, four from chemistry, three from meteorology, two from mathematics, and one each from geology and a combined mathematics, physics, and chemistry program. Achievement levels ranged from students who were struggling to pass their courses to high-achieving honors students.

The semi-structured interviews, which lasted about an hour, were carried out by the author in her office. The questions that guided the interviews are shown in Appendix A. All interviews began with the same question but subsequently the interviewer followed the informants' lead, resulting in variations in the amount of time spent discusing each question and the order in which they were raised. Occasionally there was not enough time to cover all the questions.

Analysis was based on transcripts of the interviews following the guidelines set out by Strauss and Corbin (1990).

Because of the small number of subjects and because all attended the same university the results can be taken only as an indication of topics that could profitably be studied further. However, some of the themes that emerged are sufficiently consistent with related literatures on university students and mature scientists to lead to confidence in their validity.

Results and Discussion

A number of themes emerged that are relevant to understanding problems in attracting and retaining students in math/science, and on most there were no gender differences. However, when students talked about their relationships with peers and professors, clear gender differences did emerge, with eight females but no males expressing difficulties in these areas.

Interpersonal Networks

Peer groups. Peer groups were important to students. They were often required to work together in labs or on group assignments and they frequently formed informal study groups to help cope with the heavy workload. Women students often felt marginalized in these groups. Sometimes, the exclusion was subtle:

> They use a tone that is not the same they would use for a guy. It bothers me.... They make step by step explanations, but they wouldn't discuss or argue the way they would with a guy.

At other times the exclusion was more open, but presented as "fun":

> Usually the girls of the physics department, they will work together in the labs.... So some of them make a bit of fun out of you. They will say "finally the girls got the result from the experiment. They managed to do this. It's almost incredible but they got an answer, they got a good result."

For many students the study groups become the basis of their social lives. Although not all students wanted their social and their school life to overlap, only females expressed concern about their peripheral position. They searched for explanations, sometimes coming up with several over the course of the interview: the university, the city, the program, their own fear of "butting in" to a male group. The most frequent explanation was that the woman herself was somehow responsible for her alienation. One woman expressed her self-doubt clearly: "I was never really sure, was it only me or was it because I was a girl."

Each of these explanations is reasonable. However, all would apply equally to the men, yet not one reported the difficulties that were almost universally expressed by the women. Furthermore these results are consistent with previous reports by female graduate students (Dagg, 1990; Widnall, 1988) and working scientists (Gornick, 1983). Consequently, the explanations must be sought elsewhere.

The evidence from the women themselves as well as from other studies suggests that their problems arose from being in a minority. The difficulty in butting in to a group of individuals who are "just among themselves" is real, particularly since some men made fun of the women and gave the impression that they considered themselves superior.

Professors. Most students complained about the quality of teaching, however after their first year of studies was successfully completed the male students frequently began to see themselves as junior colleagues to professors. None of the women made statements that implied this type of relationship.

Many women expressed the feeling that their gender sometimes had a detrimental influence on their relationship with professors. They struggled in the interviews to describe and understand their experience. A third year student reflected on the difficulty she had in pinpointing the problem when she said "You wonder how much is sexism and how much isn't." She observed that some women had more difficulty than others. Some female students "seem really serious and seem really bright and also so absorbed in science that there is nothing else for them. You don't see any type of sexism towards them." On the other hand, she suggested that "girls with long hair, make-up, short skirts, anything, they want to talk about guys, whatever.... you see them getting a lot of flack."

Implications of Gendered Relationships. These women who tried to evaluate the extensiveness and the importance of their marginalization in intellectual and social relationships. Many made it clear that the problem was not all-pervasive. One explained "You run into some of the older profs who can be a bit male chauvinist but its been fairly rare."

Many minimized their difficulties. For example, the woman who described the hazing that some females received in her lab said about it "Personally I didn't have problems with this." Another woman objected when a professor refused to let her hold open the door for him because it made her feel she would have to "do just that much more academically". Yet she went on to say "I don't really see myself as being stopped or put back or put down in any sense."

None-the-less, the social isolation from professors and peers already put females at a disadvantage in finding work. Male students assumed that professors could be approached for help in finding work and they reported receiving both solicited and unsolicited help. Not one woman reported asking for or receiving assistance.

Males were able to help each other in finding work far more than females were. For example, one man reported that a classmate "phoned the guy to recommend me and I just had to go and make an appointment. I could start two days afterwards." The help that females received from peers was limited to moral support and information.

Because success is cumulative (Merton, 1988) it is likely that the subtle discrimination that these women now face will result in a gradually widening gender gap in achievement. Additionally, the importance of personal contacts and help from teachers for making a career in science is well documented (e.g. Gornick, 1983; Roe, 1953). Also, because science is a collaborative process, individuals who have difficulty being accepted as part of a team and whose work is underestimated will have difficulty gaining recognition.

Tinto (1975; 1982) has reported that poor social integration with peers and faculty is a major cause of dropout from university, and that it influences women more than men. Yet it would not take a great deal to improve the relationships. One woman described what it was that made a few professors more approachable: "Their reaction to students' questions in class. The tone of voice.... Or even the fact that they say, 'I'm in my office at these times'."

Given the sensitivity of these women to small signals it is important to make professors aware of the messages that they give their students. There is also no reason why the in-class hazing from peers that some women described should be allowed to continue. If women are to remain in science and to advance equally with men these issues must be addressed.

Programs

Although students' reasons for choosing a specific program varied widely, there was a common element which emerged in almost every interview: they really liked their subject. They were "fascinated" and "astonished" by what they were learning. Some were attracted by the understanding that they were acquiring: "I like to know how things work and physics seems to answer those questions" and "what I like is it looks at nature and you try to describe how nature works .... then it tries to explain in a mathematical way." To them, doing science is "sort of like a puzzle" that commands their attention.

This love of the intellectual aspects of science is consistent with descriptions of practising scientists (Roe, 1953; Gornick, 1983/1990) and gifted adolescents (Subotnik, 1988). It is also consistent with the emphasis on research that is found in many science programs for gifted adolescents (e.g. Campbell, 1985; Taffel, 1987; Pizzini, 1985).

However, these university students were strongly critical of some aspects of their programs that interfered with their desire to understand. They saw little emphasis on understanding in their courses, and some even expressed the opinion that they were not expected to think until graduate school. Most found the workload was so intense that they simply did not have the time "to study and to try to understand". Additionally, they complained that the rigid programs gave them little opportunity to explore new interests or to pursue topics in depth.

Complaints of the extreme workload came from students of all levels of ability. A top student in his final year described how, during his first year, he

> just got up in the middle of the night and I was just shaking and breaking out in a sweat.... The doctor looks me over and he says, "Go home, sit around for three days. Don't open a book." So I took his advice.... It really gets you.

Such heavy workloads are consistent with the mystique of science as a difficult subject. However, if more people are to be attracted to and remain in science it is not possible to limit the field to individuals who have no other interests and can devote their lives entirely to their field. Furthermore, such heavy workloads and rigid programs will not necessarily attract the best students. Reports of science programs for gifted high school students frequently note the importance of giving students choices and some control over their activities (Campbell, 1985; Pizzini, 1985; Taffel, 1987), and Campbell concludes that "if the gifted have to wait to get to graduate school to do their creative best, it might be too late." (p. 311). Many gifted individuals have the potential to succeed in several areas; undoubtedly some will opt for fields that have more reasonable workloads, build on the desire to understand, and have flexibility in their programs.

Conclusion

The outcomes of this research are encouraging in that the majority of students intend to stay in the field and continue their education. Additionally, there were few gender differences. Women rated themselves more highly than men on nonscience achievement, and low ability women were less likely than other women or low ability men to plan to remain in science. Although more women intended to go directly to work without further education, the gender differences in plans to continue education were not significant.

Although males and females did not differ in their plans to remain in math/science, a number of factors were identified that may work together to produce a higher defection rate among women than among men: heavy workloads, differential perceptions of ability in nonscience fields, and social networks undoubtedly all play a role.

Although males and females complained equally about heavy workloads and rigid programs it is probable that the ultimate effects will not be gender neutral. As students move into graduate school and careers, the additional responsibilities for raising children will likely leave women with an even heavier workload than men. At the same time, women have less peer support than men for coping with demanding workloads, making it even more difficult for them to do science.

Because women perceived themselves as more competent than males in nonscience subjects, they may find it easier than men to switch to fields that allow them "spare time when you can enjoy studying" and have a social life. Also, women more often than men have the choice of working part-time or being stay-at-home parents when their children are young, thus further broadening their options. All these factors combine to make it more difficult for women to stay in math/science, while at the same time giving them more alternatives than men if they wish to leave.

Plans for Future Research

It became evident in the interviews that few students make long-range career plans. Rather, they make one decision at a time, often not considering the long-term implications. Consequently, it has been decided to interview students at a series of decision points, to find out the process by which decisions are made and the factors that influence them at each step. This will be done using ethnographic decision-tree modelling (Gladwin, 1989) which allows the researcher to develop a model of the process as understood by subjects.

This model was chosen as the most useful approach for implementing change. Although there are quantitative models which predict women's selection of science and math (Eccles, 1986; Ethington & Wolfle, 1988; Maple & Stage, 1991), they have limited usefulness in devising programs to decrease the defection rate at each decision point. The intrapsychic variables posited by Eccles are largely developed early in life, and there is little that universities can do to change variables such as parental education or student race.

In a pilot study undergraduates were interviewed to determine how they selected their current program of studies; analysis will begin in the near future. The next step will be to interview students who change their major or drop out of university, to determine their reasons for change. In the future, secondary school students will be interviewed to determine their reasons for deciding what math and science courses to take. At that stage, students who have high achievement in both nonscience and science subjects will be contrasted with students who are high in only one of the two fields. However, the influence of gender and ability will be considered at all stages.

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Appendix A

Questions used to guide the interviews

1. What are you doing right now in science?
2. How did you get into (subject)? Did your parents influence you?
3. What is it about (subject) that made you decide to study it? Is there anything you don't like about it?
4. What are your plans when you graduate?
5. People often think of (subject) as a male-dominated field. Has that been your experience?

   (Females) How is it, being a girl[1] in a male field?

   (Males) How does that affect you?

6. (Included only in later interviews after earlier respondents spontaneously brought up the topic). Have you had part time or summer jobs? What were they? How did you get them?

[1]Students referred to themselves as "guys" (males) and "girls".

Table 1

Student characteristics by program

	Program					
	General		Specialization		Honors	
	n	Percent	n	Percent	n	Percent
Gender[1]						
Female	17	(29.9)	30	(49.2)	14	(23.0)
Male	30	(30.6)	47	(48.0)	21	(21.4)
University[1]						
A	11	(16.9)	29	(44.6)	25	(38.5)
B	36	(36.7)	50	(51.0)	12	(12.2)
Year[3]						
1	13	(32.5)	19	(47.5)	8	(20.0)
2	12	(24.4)	22	(44.9)	15	(30.6)
3	18	(27.6)	34	(52.3)	13	(20.0)
4	4	(50.0)	3	(37.5)	1	(12.5)

[1]Chi-square = .15; df = 2; p. > .05.

[2]Chi-square = 17.48; df = 2; p. <.01

[3]Chi-square = 4.34; df = 6; p. > 05

Table 2

Influence of Gender and Ability on Students' Plans

	Plans					
	Science		Nonscience		Other	
Gender[1]	n	%	n	%	n	%
			High Ability[2]			
Female	12	(85.7)	1	(7.1)	1	(7.1)
Male	12	(75.0)	2	(12.5)	2	(12.5)
			Average Ability			
Female	21	(91.3)	1	(4.3)	1	(4.3)
Male	40	(83.3)	0	(0.0)	8	(16.7)
			Low Ability			
Female	6	(40.0)	2	(13.3)	7	(46.7)
Male	20	(76.9)	4	(15.4)	2	(7.7)
Totals	111	(78.2)	10	(7.0)	21	(14.8)

[1]Because of low expected values in the other categories, a chi-square tests for the effects of gender was carried out on the science category only: $X^2 = 4.67$; df = 2; $p. < .10$.

[2]X^2 for the effects of ability = 10.73; df = 4; $p. < .05$.

Table 3

Students' Plans for Education or Work

	Plans			
Gender	Job[1]	Education[2]	Educ. Plus[3]	Unsure[4]
Female				
n	28	17	7	6
%	48.3	29.3	12.1	10.3
Male				
n	28	39	16	15
%	28.6	14.4	16.3	15.3
Totals				
n	56	56	23	21
%	35.9	35.9	14.7	13.5

[1]χ^2 for all categories = 6.17; df = 3; p = .10.

[2]χ^2 for gender differences in job = 3.95; df = 1; p. < .05

[3]χ^2 = 1.11; df = 1; p. > .05.

[4]χ^2 = .48; df = 1; p. > .05.

[5]χ^2 = .66; df = 1; p. > .05.