# Talking About Leaving

## Why Undergraduates Leave the Sciences

Elaine Seymour and
Nancy M. Hewitt

WestviewPress
*A Division of* HarperCollins*Publishers*

Published in 1997 in the United States of America by Westview Press, 5500 Central Avenue, Boulder, Colorado 80301-2877, and in the United Kingdom by Westview Press, 12 Hid's Copse Road, Cumnor Hill, Oxford OX2 9JJ

A CIP catalog record for this book is available from the Library of Congress.
ISBN 0-8133-8926-7 (HC)

The paper used in this publication meets the requirements of the American National Standard for Permanence of Paper for Printed Library Materials Z39.48-1984.

10 9 8 7 6 5 4 3 2 1

# Contents

# 1

# Overview

## Background to the Study

Whenever traditional practices are called into question and new practices are proposed, it is always worth asking, Why at this time? Who seeks these changes? Who resists them? and, By what rhetoric do they support their positions? When our study began in the spring of 1990, concern that there might be something fundamentally wrong with science and mathematics education was just beginning to be expressed. In 1995, at the time this book was in preparation, a national movement was already underway to improve the quality of, and increase participation in, science and mathematics education from kindergarten to graduate school. As we shall illustrate, the debate which prompted this movement had a number of sources and dimensions, not all of which were academic, and the nature of the argument changed over time. Three issues were dominant at the outset: science and mathematics education was failing to foster science literacy in the population; too few undergraduates and graduates were recruited and retained to meet the nation's future needs; and the sciences recruited too exclusively among white males—thereby depriving the nation of the talents of women of all races and ethnicities, and of men of color.

From the mid-1980s, the Higher Education Research Institute (H.E.R.I.) at U.C.L.A. drew attention to a decline in the percentage of freshmen choosing to enter and remain in mathematics and science-based majors (Astin, 1985; Astin et al., 1985, 1987; Dey, Astin & Korn, 1991; Astin & Astin, 1993). Their findings were based on longitudinal surveys of large national samples of freshmen at two- and four-year institutions. In a series of articles based on Cooperative Institutional Research Program (C.I.R.P.) data,[1] Green (1989a, 1989b) described a twenty-year decline in freshman interest in undergraduate science majors (from 11.5% in 1966 to 5.8% in 1988), with an abrupt drop from 1983. The largest portion of this decline was evident in mathematics (from 4.6% to 0.6%) and the physical sciences (3.3% to 1.5%). Between 1966 and

1989, freshman interest in mathematics fell by four-fifths. The sharpest, most recent decline in enrollment occurred in engineering and computer science (from 12.0% in 1982 to 8.6% in 1988).

The future for all of these disciplines appeared to be further undermined by: a decline in the proportion of students choosing careers in science and mathematics teaching (from approximately 22% of freshman in 1966 to approximately 9% in 1988); a shift toward the preparation of science and mathematics teachers through education, rather than via disciplinary, majors; and a growing disinclination among young women to choose a career in high school mathematics teaching. Green refers to this as the loss of a "captive population" of women who, historically, had been "a key resource in the pool of potential science instructors, as well as key role models for women" (1989b, p. 37).

The American Freshman surveys, and (by 1991), U.S. Census data, clarified that potential graduates in science, mathematics and engineering (S.M.E.) were lost in the transition from high school to college by undergraduate switching into non-S.M.E. majors, and by declining enrollment in advanced S.M.E. degrees. Collectively, these losses began to be referred to as "leakage" from the S.M.E. "pipeline." In their 1993 C.I.R.P. report, Astin and Astin indicated that between freshman and senior years, S.M.E. majors suffered a relative student loss rate of 40 percent. Losses ranged from 50 percent in the biological sciences and 40 percent in engineering to 20 percent in the physical sciences and mathematics (when the transfer of former engineering majors into these disciplines is taken into account). Taken as careers, both engineering and the health professions lost over half of their entrants (53% and 51% respectively). The National Science Foundation (N.S.F.), the National Academy of Sciences, and the Office of Technology Assessment (O.T.A.) were among the first public bodies to debate the extent and causes of problems in science education and to promote discussion of ameliorative action. A 1987 National Academy of Sciences discussion paper concludes:

> There is still movement into the mathematics, science and engineering (M.S.E.) pipeline during the college years. However, at each stage, the net effect of the movement in and out of the pool is loss. The cumulative impact of these losses is substantial. Over 50 percent of the high school seniors surveyed dropped out of the M.S.E. pipeline by the end of their first year in college. Some returned later on. However, by college graduation, only 35 percent of the high school seniors who planned on M.S.E. majors had stayed with their plans. This suggests that, during the college years, more attention should be paid to preventing migration out of science (p. 29).

*The Report of the Task Force on the Engineering Student Pipeline* (Engineering Deans' Council, 1988) also estimated the rates of loss to other majors, and from school altogether, as varying between 30 percent and 70 percent in four-year engineering schools (where deans and faculty gathered the data). They discovered that few engineering schools maintained longitudinal retention data in which the persistence of freshmen cohorts was tracked.

This pattern of loss was also documented in a series of collaborative studies by the N.S.F. and U.S. Department of Education (cf., N.S.F., 1990a), and in the work of Hilton and Lee (1988). The greatest losses (estimated at between 34% and 40%) were found among high school graduates who abandoned their intentions of entering an S.M.E. major at or before college enrollment. During college, the highest risk of S.M.E. switching (a further 35%) occurred in the transition from freshman to sophomore year, and included those who moved into other majors and those who left college altogether. Hilton and Lee reported the loss between freshman and junior years as two percentage points (from 7.5% to 5.4%). From the start of junior year to graduation, the attrition rate dwindled to 0.8 percent. Very few students transferred into S.M.E. majors after college enrollment, and there was always a net loss. These estimates were thought likely to be conservative as many institutions do not require formal declaration of major until the end of sophomore year when the primary period of risk is already past.

As to gender differences in losses from the sciences, Strenta and his colleagues (1993) reported the persistence rates of men in S.M.E. majors varied between 61 percent for highly selective institutions to 39 percent for national samples, while the comparative rates for women ranged between 46 percent and 30 percent. Astin & Astin (1993) observed that absolute losses were greater among men, but, because the proportionate loss of women was greater, their under-representation increased during undergraduate S.M.E. education. In the same report, they documented high loss rates among that smaller proportion of S.M.E. entrants who are Hispanic, black, or native American. Only one-third of Hispanics, one-half of blacks, and one-half of native Americans who enrolled in S.M.E. majors graduated in them.

Some academic commentators also expressed concern that S.M.E. losses came from a pool of disproportionately able undergraduates (Green, 1989a, 1989b; White, 1992). Green observes that in 1988, 45.3 percent of college entrants intending to enroll in S.M.E. majors had final high school G.P.A.s of A or A- compared with 26.3 percent for students planning non-S.M.E. majors.[2] This finding is underscored by the N.S.F.'s (1990a) report that, of high school graduates entering four-year institutions with A or A-/B+ grades and at least 10 semesters of math and science, a consistently higher proportion entered S.M.E. majors than entered non-S.M.E. majors. Approximately 20 percent of the same well-prepared, high-ability group entered lower-level colleges, and another 20 percent did not enroll in any type of college. Able students were lost both immediately before S.M.E. enrollment and at some point over freshman and sophomore years. Green (1989b) summarizes his concerns thus:

> Not only do the sciences have the highest defection rates of any undergraduate major, they also have the lowest rates of recruitment from any other major. In short, science departments lose a huge proportion of their potential clients—the academically-able and intellectually-motivated students who enter college with a genuine interest in studying science (p. 478).

Declining enrollment in advanced S.M.E. degrees by American-born students also attracted alarm (cf., Atkinson, 1990; Hilton & Lee, 1988; Massey, 1989; O.T.A., 1989; Pool, 1990; N.S.F., 1990a). Hilton and Lee (1988) described the failure of able S.M.E. undergraduates to continue into graduate school as the second greatest source of loss from the pipeline.[3] The 1989 O.T.A. report blamed stagnation in the academic job market and observed, "Graduate enrollments have been sustained largely by foreign students who have helped to compensate for the decline in enrollments by U.S. citizens" (p. 9). The 1992 edition of National Science Indicators (N.S.F., 1993a) also reported that between 1971 and 1991 the number of science and mathematics doctorates awarded to non-U.S. citizens rose 135 percent (170 percent in engineering), while those awarded to U.S. citizens fell by 10 percent (19 percent in engineering). A National Academy of Sciences analysis of the bi-annual Survey of Doctoral Recipients (cf., N.S.F., 1990a) estimated that in 1988, foreign students accounted for more than 28 percent of Ph.D.s in science, mathematics and engineering.

While the academic community was discussing the implications of these studies, public debate about the state of science and mathematics education focused on information of a different but related kind; namely, international studies comparing school children's achievements. The 1988 report of the International Association for the Evaluation of Educational Achievement received particular media attention. In comparing the achievements of U.S. children and those of 17 other countries, it found only average levels of competence in mathematics and science for U.S. 10 year-olds, which, by age 14, dropped to 14th place, and to the lowest ranks by the end of high school. This concern has recently been moderated, but not assuaged, by re-evaluation of national and international data.

One important consequence of the public debate generated by this body of work has been an effort, spearheaded by the National Research Council, to establish teaching and assessment standards for K-12 mathematics and science education (cf., N.R.C., 1993). However, these standards are not (unlike those of many other countries) mandatory.

Evidence of declining scientific literacy in the population, and of reduced numbers of S.M.E. graduates available for research, development, or teaching, has also generated expressions of concern that America's international competitiveness in the science and technology-dependent sectors of the U.S. economy would be undermined as a consequence of these trends:

> From a broader perspective, there is a growing concern over our country's future ability to compete in the global market (Mullis & Jenkins, 1988, p. 5).

> The U.S., two decades ago, led its economic competitors in the number of scientists and engineers it produced relative to its population. But, today, Japan—with half the U.S. population—produces more engineers than the U.S. (N.A.S.U.L.G.C., 1989, p. 36).

Arguments of this nature gave strong impetus to initial efforts to revitalize science education, although they have more recently been called into question. As Gomory and Cohen have argued (1993), some important growth industries, and the countries that have profited most from them, depend more on good design, production techniques, and marketing than on international leadership in academic science. Nevertheless, expressions of economic nationalism, and anxieties about the nation's prosperity in the fast-approaching second millennium seem likely to fuel science education reform efforts for some time to come.

The response of the academic and professional community has been differently expressed. A series of commissions, task forces, conferences, and working groups—sponsored by the N.S.F., the National Academy of Sciences, Sigma Xi, the National Association of State Universities and Land Grant Colleges (N.A.S.U.L.G.C.), and the American Association for the Advancement of Science (A.A.A.S), and others—began to collectively brainstorm the causes and consequences of low interest in, and high attrition from, mathematics and science at all educational levels. The most influential of these include the 'Neal Report' (N.S.F., 1986), the Report of the Disciplinary Workshops on Undergraduate Education (N.S.F., 1988), and the Sigma Xi "Wingspread Conference" of the National Advisory Group (1989). Each represents the collective wisdom and experience of higher education administrators and educators, officers of learned bodies, and representatives of the scientific community, industry and government. The Neal Report pointed to flaws in the undergraduate experience: lab instruction, at worst, was said to be "uninspired, tedious and dull"; lab facilities and instruments were described as limited and "obsolete"; teaching was inadequate and poorly organized and reflected little knowledge of modern teaching methods; teaching materials were out of date, and curricular content failed to meet students' varied and emergent career needs. The report segmented its account by types of institution, disciplines, and to some degree, by the special difficulties of under-represented groups. It also noted a decline in the number of S.M.E. graduate students choosing academic careers, and thus a growing shortage of engineering faculty since 1976 and of mathematics faculty since 1981. Surveying the condition of undergraduate S.M.E. education overall, it warned that, "all sectors of undergraduate education in mathematics, engineering, and the sciences are inadequately responsive to either its worsening condition, or to the national need for revitalization and improvement" (N.S.F., 1986, p. 3).

The N.S.F. workshops on undergraduate education (1988) were divided by disciplines, and faculty identified problems common across S.M.E. undergraduate education, and specific to their own disciplines. They highlighted the second-class status of teaching compared to research: "The most important thing N.S.F. can do for science education is to increase the prestige and respectability of teaching" (Physics Workshop, p. 75). They also pointed to, "inadequate pre-college instruction,...deteriorating instructional facilities, and lack of funding for research efforts involving students" (Geo-science Workshop, p. 3). The Chemistry Workshop specifically identified "widespread, fundamental and long-standing problems in lab instruction in chemistry [as having] the greatest effect on retention of students...in the first two years of the undergraduate curriculum" (Chemistry Workshop, p. 5).

The National Advisory Group of Sigma Xi (1989) focused on problems with the physical and pedagogical context of undergraduate learning, insufficient accountability and flexibility in curricula, and the unmet needs of traditionally under-represented groups. Losses from S.M.E. majors were thought to reflect a poor balance between faculty research and teaching, large classes, inadequate academic and emotional support for students. They were also a consequence of using entry-level courses as a gate-keeping mechanism, "to protect more advanced courses from all except the most able, and the most committed" (p. iv). An important new note was, we feel, struck: "In addressing these topics and some of their concomitant issues, it became evident that attitudes and perceptions are, in themselves, significant topics" (p. vi).

The forum approach highlighted many elements likely to have bearing on the causes of S.M.E. attrition. However, without systematic investigation we could not know whether all of the pertinent issues had been raised, or which elements mattered more than others. Furthermore, even at the Sigma Xi meetings—where it was recognized that, "students' perceptions of the undergraduate curriculum in science, mathematics and engineering, and the faculty perceptions of the same curriculum, are by no means congruent" (p. iv)—the perceptions of students were not solicited.

The O.T.A. reports (1988, 1989) addressed attrition by comparing studies of S.M.E. baccalaureate productivity in higher education institutions of different types. They documented the better record of liberal arts and historically black colleges and of technical institutions, compared with state and research universities. They cited the self-study programs of the 50 private liberal arts colleges in the 'Oberlin Group' which identify the features of undergraduate education found to work in favor of higher S.M.E. completion rates: higher selectivity in enrollment, lower faculty-student ratios, and higher faculty-student interaction (monitoring, advising, counseling, and student involvement in faculty research). Replication of these conditions was argued to reduce the risk of attrition. Porter (1990) also found higher completion rates in those colleges with smaller classes, enhanced contact with faculty, and greater enrollment selectivity. Knowing 'what works' in smaller, privileged, and highly selective settings does not necessarily constitute a test of what causes or cures attrition in other contexts, nor does it tell us what else might work. Nevertheless, the greater success of small liberal arts colleges in recruiting, and retaining, science and mathematics majors (including women and students of color) has prompted some larger institutions to consider their methods. It has also encouraged groups of smaller institutions to build on their success by promoting what they perceive as the best ways to present science and mathematics to undergraduates. The longest-established, and most wide-ranging of these endeavors is that of the Independent Colleges Office "Project Kaleidoscope" (1991, 1992, 1995).

An overarching concern reflected in many reports, studies and commentaries in the late 1980s was that, by the end of the century, the nation would face a shortfall in the supply of qualified scientific and technical personnel at all levels (cf., N.S.F., 1990a, 1990e; Atkinson, 1990; Pool, 1990; N.A.S.U.L.-G.C., 1989). Although this fear subsequently proved unjustified, and is increasingly being replaced by the concern that graduates from particular disciplines, especially physics, are actually facing underemployment and unemployment, it nevertheless played an important early role in promoting the reform of science education.

Tobias (1990, 1992a), Heylin (1987), and others have pointed to the significance of another widespread belief in shaping the way that recruitment and retention issues have been addressed—that the ability to understand mathematics and science is limited to a relatively small proportion of the population:

> Chemistry, and much of the rest of science in this country, has been working for far too long under an implicit assumption that scientific competence is disproportionately concentrated in that roughly 40 percent of the population represented by white males (Heylin, 1987, p. 3).

This assumption bolsters a related belief—that some, even most, switching from S.M.E. majors is 'appropriate' or 'normal' (cf., N.S.F., 1990a). S.M.E. faculty expect some fallout (even at a fairly substantial rate) because those presumed to lack sufficient natural ability to continue are thought to discover their limitations, and/or their true vocation for some other discipline, and leave. By this perspective, the function of the traditional 'weed-out' system is to assist this process. Where S.M.E. attrition is regarded as largely inevitable or appropriate, recruitment rather than retention is seen as the appropriate way to address pipeline concerns. The perceived shortfall crisis, therefore, prompted a search for mathematics and science talent in populations which had, hitherto, received less attention, namely, women, students of color and students with disabilities. Interest in non-traditional groups as a source of S.M.E. enrollment also coincided with growing concern (expressed by researchers, educators, and the professional and academic associations of women and minority groups) that women, students of color and students with disabilities were under-represented among S.M.E. undergraduates and graduate students, faculty and administrators for reasons other than ability. (The debate about why this has occurred, and the research which informs it, are discussed briefly below, and in more detail in Chapters 5 and 6.) The movement to increase the participation and retention rates of under-represented groups has yielded disappointing results despite considerable outlays of money and effort.[4] This can be explained, we suggest, by unresolved contradictions in its focus and strategy. If programs addressing under-representation are primarily shaped by a search for undiscovered talent, while the structural and cultural barriers to enrollment and persistence among under-represented groups remain obscure or unaddressed, such programs cannot succeed.

***Reasons for Attrition among S.M.E. Majors***

Prior to 1990, there was no body of work that had explored the range of factors contributing to attrition among both male and female undergraduates, different racial or ethnic groups, and different S.M.E. majors. Theories of attrition based on research tended to be limited in scope. Studies focused on particular groups (often women), were offered as by-products of research into other issues, addressed one possible cause of attrition (e.g., inadequate high school preparation), or used one kind of theoretical approach (e.g., institutional data analysis, or psychological theories of motivation). Some of the commonest observations on S.M.E. attrition had no basis in research at all. For example, several national reports speculated that increases in the numbers of foreign teaching assistants and faculty were a likely source of impediments to the progress of women in S.M.E. majors. Among these, Vetter writes:

> A growing problem for American students is the language barrier between them and many of their foreign teaching assistants and faculty. While this is a problem for both sexes, foreign teachers are said to provide an additional handicap for women...The retention rate for women in engineering, from freshman year to bachelor's degree, has dropped drastically...It may reflect some of the student-faculty problems for women who must work with foreign men in what the latter may perceive as a submissive role (1988, p. 737).

Although the validity of this supposition had never been tested, its repetition allowed attention to be diverted from the experience of female S.M.E. students with American-born faculty and peers. Concentration on what were, perhaps, peripheral difficulties, in effect, circumvented inquiry into the significance for attrition of mainstream cultural practices.

The only national data on the causes of S.M.E. attrition are those derived from the National Longitudinal Survey and the 'High School and Beyond' surveys conducted by the Department of Education.[5] Students were found to switch out of S.M.E. majors into other majors for two main reasons: 43 percent said that they found non-S.M.E. majors more attractive (a finding similar to that of the University of Michigan study [Manis et al., 1989] discussed later in this section), and 31 percent stated that they found the work 'too difficult'. Unfortunately, these findings raise more questions than they answer, including what students mean by the 'hardness' of science, mathematics and engineering. Nor do we learn what elements of students' experiences in S.M.E. courses were so unsatisfactory that other disciplines seemed more appealing.

Faculty opinion surveys were also a source of attrition theories. A Carnegie Foundation (1989) survey of 5,500 faculty in all disciplines reported that nearly three-quarters of faculty thought undergraduates were seriously under-prepared in academic and study skills. The accuracy of this perception, and the role played by under-preparation in S.M.E. attrition, were unknown. However, work by Strenta and his colleagues (1993) on the causes of attrition among women at highly prestigious institutions called into question the significance of pre-admission measures of 'developed abilities', compared with women's adverse reactions to negative pedagogical and peer group experiences in their first two years.

The only studies of attrition grounded in actual student experience were those which explored the problems of women in science and engineering majors. Studies of female S.M.E. graduate students reported psychological alienation, and lowered self-esteem as common responses to their graduate school experiences and as significant factors in their decisions to leave. The Illinois Valedictorian Project (cf., Widnall, 1988) which followed the college progress of 80 high school seniors of high ability (both male and female) also reported a significant loss by sophomore year of previously high self-esteem among women, and a lowering of career ambitions despite high performance levels. Over the same period, the self-esteem and career aspirations of their male peers rose. Some clues to understanding this phenomenon arose from the findings of a series of studies sponsored by the American Association of Colleges (Hall & Sandler, 1982, 1984, 1986). Hall and Sandler described the experiences of women students, faculty, and administrators in the sciences as "chilling." They documented the rudeness of male peers experienced on a daily basis, and the role of undergraduate instructors in maintaining classroom inequalities, both by disattention and by overt discrimination. Where faculty conveyed messages of lower expectations for women, women of high ability were prompted to lower their academic and career ambitions and to under-achieve.

Studies of persistence among students of color in all majors alerted researchers to another factor in attrition—the negative consequences for academic progress of insufficient financial support. Mohrman (1987), Rotberg (1990), Wilson (1990), and Porter (1990), discussed the disproportionately negative consequences for students of color of reductions in the level of public support available to all students. Mohrman predicted that almost one-third of low-income students of all racial and ethnic groups would drop out of school completely if public grants were to be eliminated. Wilson found students took longer to complete their baccalaureates, or dropped out, partly because they could not meet their college tuition and everyday living expenses. While students of color had the lowest college completion rates for reasons which had not been explored or explained, the very highest drop-out rates occurred among students of all races and ethnicities who did not receive grants. Rotberg reported debt burdens to have greatest impact on the college attendance rates of students of color because both their family resources and their expected future earnings tended to be lower. Other aspects of student financial problems with bearing for attrition were: the increasing cost of higher education at a time of inflation; a decline in the real value of student aid as a percentage of tuition costs; and the creation of a debt burden for half of all graduates by a shift in emphasis from grants to loans. Porter found that four-year degree programs were no longer a viable option for most undergraduates. Most undergraduates who left college did so in freshman year: those with federal grants showed significantly more persistence beyond the first year than those without them. He also found financial problems were especially acute for students of color, and the main cause for high college drop-out rates among Hispanics and blacks at four-year institutions was breakdown of their attempts to carry full course loads while working to meet tuition and living expenses.

Several different approaches are discernable in those few studies which have directly sought reasons for S.M.E. attrition. The development of predictive models by which to identify those students who are most likely to persist is exemplified by the work of Levin and Wyckoff (1988) among engineering students. Ability in mathematics was found to be the best single predictor of engineering success (better than S.A.T., college or high school G.P.A. scores), followed by choice of an S.M.E. major on the basis of interest in the subject. Though models predicting individual success in S.M.E. classes are useful for development of better screening procedures, they are limited as ways to explain attrition rates which are disproportionately high among particular groups.

Silberman (1981) and Carter and Brickhouse (1989) explored the learning problems of S.M.E. students by comparing the beliefs of faculty and students about the nature of science. They reframed the attrition issue as: What makes a subject so 'difficult' that some students drop out or fail? In a study of 1,200 students taking Chemistry 116 at Purdue University, they found that the 'difficulty' of the class was very differently perceived by the students who took it, and by the faculty who taught it. Faculty took a more determinist view of students' chances of mastering the material: they believed the subject material was inherently hard, and expected a certain proportion of the students in each cohort to be unable to 'get it'. They conceded, however, that hard material might be mastered with sufficient background knowledge, interest and effort. Students did not accept the 'inherently difficult' view of the material. They maintained a 'democratic' theory of education, believing it should be possible to teach so as to clarify the complexities of chemistry for students who were adequately prepared: such students should be able to 'score' good grades with sufficient personal effort and faculty help. They also stressed remedies within the control of the individual student or teacher more often than did faculty. This is a particularly useful line of inquiry because it begins to clarify what frustrates students about 'hard' classes, and identifies some sources of faculty resistance to pedagogical reform initiatives. The academic difficulties experienced by many S.M.E. students, and the apparent difficulty of many faculty in responding to them, may be visualized as a structural conflict between the élitism and predestinarianism of science (cf., Merton, 1942, 1970, 1973) and the democratic, consumerist approach which students bring to college from high school and the wider society.

Five bodies of research which illustrate the value of seeking to understand how students process their experiences in S.M.E. classes, and the conditions under which they function well are: the work of Manis, Sloat, Thomas and Davis at the University of Michigan on factors affecting choices of S.M.E. majors (1989); Tobias' (1990) exploration of the introductory science and mathematics class experiences of high ability students from other disciplines; Lipson's (1992) secondary analysis of interview data from the Harvard-Radcliffe study of women in science (cf., Tobias, 1990); Treisman's series of calculus teaching experiments at Berkeley (cf., Treisman, 1992); and those of Hudson (1986) in physics at the University of Houston. Manis and her colleagues interviewed: high-ability women who had decided not to enter science majors; women who entered them, but left; women who remained through to senior year; and matched samples of men. At the end of freshman year, 71 percent of all women reported a variety of negative experiences in S.M.E. classes, and 61 percent described specific class experiences (most commonly in mathematics and chemistry) which had dampened their interest in science and undermined their motivation to continue. The characteristics of such classes were (in order of importance): poor teaching or organization of material; hard or confusing material, combined with loss of confidence in their ability to do science; cut-throat competition in assessment systems geared more to weeding out than to encouraging interested students; dull subject matter; and grading systems that did not reflect what students felt they had accomplished. Many of those who stayed in science also complained about poor teaching and an unpleasant atmosphere. Male students who had gone through the same experiences were much less troubled by the competitive atmosphere, the grading system, and the dullness of the subject matter. Both male and female switchers reported that negative experiences in freshman science were more important than positive experiences in other fields in reaching their decision to leave. Sophomore switchers confirmed the salience of the issues raised by freshmen, and cited the quality and availability of faculty advice and support as critical in their decision to persist or leave.

Tobias (1990) approached the issue of the leaking pipeline by asserting the existence of a 'second tier' of untapped scientific ability among able people who choose to work in other disciplines, but possess sufficient interest and preparation to pursue S.M.E. fields. Such people might, she proposes, be persuaded to enter, or return to, science were a more flexible approach to curriculum and teaching methods adopted, and different modes of thought accommodated. Tobias found seven high achievers in other fields (five women and two men, including one faculty member) who had considered, but rejected, a career in science, but who were sufficiently well-prepared to take freshman or sophomore science and mathematics classes, and asked them to undertake one semester in a science or math class of their choice. Her findings from this experiment are derived from each participant's diary of their learning experiences, and from open-ended interviews. Her participants described the 'apprenticeship model' of scientific pedagogy, and the 'maleness' of its culture. They offered detailed commentaries on the thinking processes required by science and mathematics, and how these differed from those to which they were accustomed in other disciplines. They commented on the counter-productive effects of curve-grading, and aggressive competition among peers, and faulted the narrowness of syllabus content and lack of application in the teaching of concepts. Two of the seven volunteers reported they had struggled with a desire to abandon the experiment before the end of the semester.

Tobias's monograph includes an account of Lipson's (1990) secondary analysis of qualitative interview materials from a longitudinal data set of Harvard-Radcliffe women in science (Lipson, 1992; Ware et al., 1985, 1986, 1988). Lipson draws on interview data with first-year S.M.E. switchers and persisters in order to clarify the issues contributing to their decisions to stay, or to move into non-science concentrations. She found a pattern in which persisters evoked external explanations for their difficulties in science courses, while switchers cited their own inadequacies as the cause. Switchers rejected the culture of competition, and felt that commitment to science meant losing the chance of a well-rounded, liberal education. These findings square with those from several other studies of college women, as reviewed by Widnall (1988) and Baum (1989).

Treisman's work is important because, along with Tobias's earlier work on math anxiety (1978), it questions the assumption that the pool of people 'able' to tackle mathematics or science is limited. It calls into question theories of attrition based on extrinsic variables rather than learning experiences. It also offers empirical support for a student-centered approach to mathematics teaching which, though not uncommon in other disciplines, has not been widely employed in the traditional pedagogy of mathematics, science, or engineering. In a now-famous series of experiments, Treisman identified, and successfully replicated, the interaction and study patterns of Asian-American students who did well in his calculus classes with black students who performed poorly. He discovered that key elements in student success were: group study and support; students' awareness of their teacher's high expectations; the shared experience of success in solving problems of a progressively challenging nature; and the building of self-confidence. Jaime Escalante's success in preparing minority students from poor East Los Angeles families for the Advanced Placement test in calculus, and Bonsangue and Drew's (1992) evaluation of a calculus workshop program for Latino students built on the Treisman model, suggests that Treisman's success cannot be dismissed as a function of the high intellectual calibre of his Berkeley students or of his own high ability as a teacher. As the classic Hawthorne experiments of the 1930s remind us, the strong effects in a desired direction created in a group that feels its performance is a matter of special importance to the experimenter (in this case, the teacher) should not be underestimated (cf., Mayo, 1966). Hudson's earlier (1986) experiment with students in introductory physics classes also underscores Treisman's results. Hudson found that weaker performances could be improved by making assessment practices serve as a learning tool: where the results of tests were given to students in a diagnostic manner with feedback on specific areas of weakness and with time to remedy learning difficulties in a program of self-study, students with lower scores for mathematical and reasoning ability were able to perform to the required class standard.

The implications of this body of research and experimentation are clear: S.M.E. attrition cannot be viewed as a natural consequence of differential levels of ability; classroom climate and activities play critical roles in determining the students who do, and do not, persist within S.M.E. majors. However, when we began our own study in the spring of 1990, the work of teasing out the whole range of factors contributing to high S.M.E. attrition rates had not been attempted, despite some promising leads in particular directions. Nor had a framework been developed to express the relative contribution of different factors to each other. It was this combination of tasks which we set out to accomplish.

## Study Objectives

In the spring of 1990, we began a three-year study whose aim was to discover, and to establish the relative importance of, the factors with greatest bearing upon the decisions of undergraduates at four-year colleges and universities to switch from science, mathematics and engineering majors into disciplines which are not science-based. On the presumption that the institutional context in which science, mathematics and engineering education takes place is likely to have some effect on retention and attrition, we chose seven institutions to represent the types of four-year colleges and universities which contribute most to the national supply of baccalaureate scientists, mathematicians and engineers. Because information about the causes of S.M.E. attrition was limited, we made no presumptions about the kinds of factors which might be involved, nor about their relative importance. We adopted an ethnographic approach which was grounded in the assumption that undergraduates are expert informants who are well-placed to describe the strengths and limitations of their educational experiences: where students abandoned their intention to major in an S.M.E. discipline, only they can explain how they weighed particular elements in the network of events leading to their decision. We assumed that particular pieces of information (especially high school preparation, class grades, S.A.T. math scores, G.P.A., etc.), were likely to have important bearing on their educational fortunes. However, without some understanding of how students interpret and respond to these biographical facts, their actions cannot be predicted or explained.

Within our overall aim for the project, we included a number of specific objectives:

* to identify sources of qualitative difference in the educational experience of science, mathematics and engineering under-classmen at institutions of different types

* to identify aspects of the structure, culture, pedagogy, or other features of science, mathematics and engineering departments, schools and colleges which encourage attrition or impede retention for the whole undergraduate population, and for important sub-sets of it

* to compare and contrast the causes of attrition from science, mathematics and engineering majors found among male students of color, and among women of all races/ethnicities, with those of white males

* to estimate the relative importance of the factors found to contribute to S.M.E. attrition

As most departments and colleges do not keep enrollment, persistence, and attrition records, our first task was to establish field 'switching' and field persistence patterns by groups of disciplines. We defined 'switching' so as to include both leaving a declared S.M.E. major for a non-S.M.E. major, and declaring a non-S.M.E. major, despite an original intention to enter an S.M.E. major. Undergraduates who had moved from one S.M.E. major to another were not counted as switchers.[6] 'Persistence' was taken to mean intending to graduate, either in the S.M.E. major originally chosen, or in another S.M.E. major. We wanted to know: what proportions of undergraduates stayed in the major they originally chose or intended to enter; what proportion moved into another major in the same broad group of disciplines; what proportion moved into majors outside their original group; and how the switching and persistence patterns of S.M.E. majors compared with those who originally chose other groups of majors. Finally, we wanted to know into which majors switchers went once they had left their original majors.

As there were no published national data which compare the switching and persistence rates in S.M.E. majors with those of other majors, we asked the

Higher Education Research Institute to provide us information derived from their most recent C.I.R.P. survey data. From a set of unpublished tabulations from data on the last cohort of freshmen (1987) in the C.I.R.P. surveys for whom the H.E.R.I. had a complete four-year record (i.e., to 1991), we constructed the patterns of switching, persistence, and transfer of majors which are summarized in Tables 1.1 through 1.5.

Table 1.1 shows the pattern of persistence in, and switching from, declared or intended majors by 1991 for those freshmen who entered in 1987.[7] It portrays a continuum of stability to instability in original major choices: beginning in English, where the switching rate is very low (15%), through the social sciences, fine arts, education, history and political science, where the switching rate is 28 percent to 35 percent; through engineering and business, where it is 38 percent to 40.5 percent, to the sciences, computer sciences, and mathematics, where the range is 47 percent to 63 percent; and finally to majors geared to the needs of the non-technical and health professions, where instability is highest (62 percent to 71 percent). The picture for pre-medicine is complex because many freshmen with aspirations to enter one of the health professions initially enter the biological sciences. They may change their minds about this career path before getting to a 'pre-med' declaration.

The most stable major of the S.M.E. group is engineering, which is also the most selective in its screening procedures for applicants: 53 percent of engineering entrants stayed within one of the engineering specialties. The S.M.E. majors most vulnerable to switching are mathematics and statistics, where the loss rate is almost 63 percent. The physical and biological sciences share a similar rate of switching: approximately half of all entrants to these majors (51%) move into non-S.M.E. majors. However, freshmen who begin in the physical sciences are also more likely than those who begin in any other S.M.E. major to stay within the sciences by moving into a different S.M.E. major prior to graduation. The switching rate of 44.1 percent for all S.M.E. majors (i.e., excluding computer science, and the health professions), is very similar to that of 40 percent found by Strenta, Elliott, Adair, Scott, and Matier (1993) for well-prepared and talented students who entered four highly selective institutions in 1988. The S.M.E. switching pattern of the 1985 entrants described in the 1993 C.I.R.P. report (discussed earlier in this chapter) is also very similar to that of the 1987 entrants shown here.

In the humanities and social science groups, approximately three-quarters of the freshmen who entered their original majors in 1987 were still in them in 1992. In English, the social sciences and fine arts, over half of all entrants remained in the major of their first choice. Most of the changes in this group were from one humanities or social science major to another.

TABLE 1.1 Patterns of Persistence in, and Switching from, Declared or Intended Majors by 1991 for 810,794 Undergraduates Entering a National Sample of Four-Year Institutions in 1987.

*Based on unpublished tabulations provided by the Cooperative Institutional Research Program, Higher Education Research Institute, University of California, Los Angeles, April 1993.*

| *Original major* | *% Stayed in same major* | *% Moved to major in same group* | *% Stayed in major or group* | *% Switched to majors in other groups* |
|---|---|---|---|---|
| ***S.M.E. Majors*** | | | | |
| Biological Sciences | 42.0 | 7.1 | 49.0 | 51.0 |
| Physical Sciences | 29.9 | 18.9 | 48.8 | 51.2 |
| Engineering | 51.4 | 10.5 | 61.9 | 38.1 |
| Mathematics/Statistics | 34.1 | 3.2 | 37.3 | 62.7 |
| Math (only) | 29.2 | 8.2 | 37.4 | 62.6 |
| Agriculture | 52.8 | 0.0 | 52.8 | 47.2 |
| *All S.M.E. Majors* | *46.0* | *10.2* | *55.9* | *44.1* |
| ***Humanities/Social Science Majors*** | | | | |
| History/Political Science | 43.5 | 21.7 | 70.4 | 34.8 |
| Social Sciences | 56.0 | 16.0 | 72.0 | 28.0 |
| Fine Arts | 50.6 | 19.5 | 70.1 | 29.9 |
| English | 56.5 | 28.4 | 84.9 | 15.1 |
| Other Humanities | 28.6 | 40.2 | 68.8 | 31.2 |
| *All Humanities/Social Science Majors* | *48.1* | *26.0* | *74.1* | *29.9* |
| ***Other Majors*** | | | | |
| Health Professions | 29.4 | ---- | 29.4 | 70.6 |
| Computer Science/Technical | 46.4 | ---- | 46.4 | 53.6 |
| Business | 59.5 | ---- | 59.5 | 40.5 |
| Education | 67.7 | ---- | 67.7 | 32.3 |
| Other Non-technical | 37.8 | ---- | 37.8 | 62.2 |

In making these comparisons, we must bear in mind the different traditions of the liberal arts and the sciences. In the humanities, faculty commonly encourage students to experience different disciplines before making a final choice. By contrast, S.M.E. faculty demand early commitment from students in order to build their skills and understanding in linear fashion over time. The acquisition of a broader educational experience is, thus, more difficult for S.M.E. majors. Moving to another major, even within the S.M.E. group, is also more costly in terms of time, money and effort than changing from one humanities major to another. Those who choose the sciences are encouraged to see themselves as entering difficult and demanding majors, and those who graduate as part of an élite. Nor is switching viewed by students and faculty in the humanities and social sciences in the same way as it is in mathematics, science and engineering. As we shall later discuss, we found that students who left S.M.E. majors tended to see themselves either as 'failures' or 'defectors' (depending on the degree of choice in their decision to leave). A student who leaves the social sciences for physics is treated by family, peers and faculty as someone who has done something interesting and worthwhile. A student who leaves physics for the social sciences tends to attract criticism or concern. Thus, not only do the S.M.E. disciplines have a higher rate of switching overall (44%) than do the humanities, social sciences and education (approximately 30%), those who leave them attract negative responses from faculty, family, peers and friends, which is not the case for students who leave the liberal arts.

Table 1.2 shows the final choice of major (by 1991) of those who initially entered S.M.E. majors in a national sample of four-year institutions in 1987. Almost a quarter (24.6%) of those leaving the physical sciences moved into the humanities, social sciences and fine arts, with the highest proportion (14.4%) moving into the social sciences; 17.2 percent moved into non-technical majors which lead to professional or semi-professional occupations (largely, journalism, library/archival science, communications, law enforcement, home economics and military science). A quarter of switchers from the biological sciences (24.8%) also chose the humanities, social sciences and fine arts. However, a larger proportion of former biology majors (10.2%) moved into computer science and other technical majors than from any other group of S.M.E. majors. Far fewer former engineering majors (11.4%) switched into the humanities, and far more switched into business majors (13.9%) than from other S.M.E. majors. The most frequent final choice of switchers from mathematics and statistics majors was either a humanities or an education major (with approximately 17 percent entering each of these). However, the most distinctive characteristic of switchers from mathematics and statistics was the high proportion (8.1%) who were still 'undecided' four years later.

The dominant pattern for all switchers (whether they begin in S.M.E. majors or elsewhere) is to move into the social sciences, humanities and fine arts. This trend is enhanced by the tendency of those who begin in this group

TABLE 1.2 Final Major Choices by 1991 of 148,204 Undergraduate Switchers Entering S.M.E. Majors in a National Sample of Four-Year Institutions in 1987.

*Based on unpublished tabulations provided by the Cooperative Institutional Research Program, Higher Education Research Institute, University of California, Los Angeles, April 1993.*

| *Original S.M.E. Majors* (Total Entering) | *Non-S.M.E. Destination Majors of S.M.E. Switchers* | | | | | | | *Totals by Majors* |
|---|---|---|---|---|---|---|---|---|
| | *Computer Science* | *Health* | *Business* | *Education* | *All Humanities & Fine Arts* | *Other Non-technical* | *Undecided* | |
| *Mathematics/ Statistics* (5,651) | 5.6 (316) | 1.7 (97) | 6.2 (350) | 17.3 (977) | 17.8 (1,004) | 6.0 (337) | 8.1 (458) | 62.7 (3,539) |
| *Physical Sciences* (16,325) | 0.4 (71) | 2.5 (413) | 3.2 (525) | 1.8 (294) | 24.6 (4,013) | 17.2 (2,815) | 1.4 (230) | 51.2 (8,361) |
| *Biological Sciences* (38,614) | 10.2 (3,957) | 1.1 (442) | 3.7 (1,418) | 5.3 (2,048) | 24.8 (9,546) | 5.8 (2,258) | 0 (0) | 51.0 (19,668) |
| *Engineering* (82,400) | 6.7 (5,480) | 1.0 (860) | 13.9 (11,428) | 1.5 (1,269) | 11.4 (9,372) | 3.4 (2,797) | 0.2 (187) | 38.1 (31,393) |
| *Agriculture/Forestry* (5,314) | 8.5 (443) | 0 (0) | 0 (0) | 0 (0) | 28.1 (1,461) | 10.7 (558) | 0 (0) | 47.2 (2,462) |
| *Totals: S.M.E. to Non-S.M.E. Majors* (148,204) | 6.7 (10,267) | 1.2 (1,812) | 9.3 (13,721) | 3.1 (4,588) | 17.1 (25,369) | 5.9 (8,765) | 0.6 (875) | 44.1 (65,424) |

of majors to stay within it, though not necessarily in their major of first choice. Within S.M.E. majors overall, 'internal resettlement' accounts for 9.7 percent of all relocations, compared with over a quarter (27.3%) of all such moves in the social sciences/humanities group. Education attracts far more switchers from history and political science (25.3%) than from any other major, except mathematics, which contributes 17.3 percent of its former majors to education.

Overall, the level of transfer into S.M.E. majors from all majors defined as 'non-S.M.E.' (including those who enter as 'undecided') is modest (6.2%). The fields contributing most switchers from other groups to S.M.E. majors are the computer science and technical majors, and health profession majors, who provide 21.0 percent and 26.7 percent respectively. The biological sciences gain 20.4 percent from those originally committing to careers in the health professions. Engineering gains 13.1 percent of switchers from the computer and technical fields. The only other group to make a significant transition (8.8%) into S.M.E. majors are those who enter as 'undeclared'. Transfers into S.M.E. majors from the social sciences, humanities, fine arts, business and education combined are very small (2.8%).

The C.I.R.P. data also allowed us to clarify patterns of persistence, switching and transfer of majors by sex. Of those initially choosing S.M.E. majors in 1987, 73.7 percent were men and 26.3 percent were women. The proportion of women ranged from 14.2 percent in engineering, approximately a quarter in agriculture and the physical sciences, to 45.2 percent and 47.7 percent, respectively, in the biological sciences, mathematics and statistics. There was a striking gender difference in switching patterns in that, across a wide range of majors, women more commonly than men switched to a major outside the group of their choice. The exceptions were: engineering, English and business, where the switching rates of men and of women were very similar; and the physical sciences, fine arts, health professions and education, where the switching rates of men were higher than those of women. Whether in S.M.E. majors or the humanities and social sciences, women were less likely than men to stay in their original major, and more apt to switch to another group of majors altogether. However, switching was much higher among women who originally chose S.M.E. majors than among those who chose majors in the humanities and social sciences (52.4% compared with 35.3%). The majors in which women switchers exceed women entrants by more than 55 percent include agriculture (79.1%), mathematics/statistics (72.3%), the biological sciences (56.7%), computer science (69.2%) and the health professions (60.7%).

In S.M.E. majors overall, men show a higher propensity to persist with their original choice (58.8%) than do women (47.6%), and a lower propensity to switch to a non-S.M.E. major.[8] For almost all S.M.E. majors where data are available, women show a higher propensity than men to abandon their first choices, whether by moving into other S.M.E. majors, or out of them altogether. Women are 26.3 percent of those who choose S.M.E. majors, but

31.2 percent of all S.M.E. switchers; men are 73.7 percent of all those choosing S.M.E. majors, and 68.8 percent of all S.M.E. switchers.

The greatest proportionate loss of women by switching occurs in mathematics/statistics and the biological sciences, where women are 7.3 percent and 5.0 percent (respectively) more of switchers than of those choosing S.M.E. majors. The comparable loss of women by switching from the physical sciences is 3.4 percent, and from engineering 0.4 percent. Persistence in an original S.M.E. major is also weakest among women in mathematics and the biological sciences, although their initial representation is stronger than in other S.M.E. majors. A variation occurs in the physical sciences, where women show more inclination than men to transfer into another S.M.E. major rather than to move out of the sciences completely. This trend is also discernable, to a lesser degree, in the biological sciences and engineering. However, the numbers of such transfers are small. Only around 10 percent of all students who chose S.M.E. majors switched from one science to another.

Tables 1.3, 1.4 and 1.5 reveal a pattern of reverting to gender-related traditions in the final choice of major of those who originally selected S.M.E. majors. While male switchers from mathematics, engineering and the biological sciences are substantially recruited into computer science, few women follow this path. The non-technical professional majors recruit proportionately more men (largely from mathematics and the physical sciences) than women. The humanities and social sciences receive the highest proportion (17.1%) of all switchers. However, they are chosen by more female than male switchers from all S.M.E. majors except mathematics/statistics—from which about one-third of switchers of each sex go into the humanities and social sciences. The health professions also recruit proportionately more women than men, largely from the physical sciences. However, the gender difference in the final choices of S.M.E. switchers is greatest in education, which recruits much more heavily from female than from male S.M.E. switchers. The trend is most marked in mathematics/statistics where 45.2 percent of women switchers opt for an education major, compared with 8.5 percent of the men. However, the preference for an education major is much stronger among women than among men for all S.M.E. switchers. Interestingly, the resurgence of traditional gender-based choices following switching is least marked in engineering, where a high proportion of both men and women switchers chose business majors. Women who are former engineering majors also select a computer science major more often than do women from other S.M.E. majors, and they are slightly less inclined to chose a liberal arts major than female S.M.E. switchers.

Overall, these data reflect the importance of different cultural traditions for the sexes with respect to their academic and career choices. As we shall discuss in more detail in Chapter 5, changes of mind among young women are more culturally supported than changes of mind among young men. This is especially the case where women initially proposed to enter fields which family, peers,

TABLE 1.3 Percent of Men and of Women Who Persisted in and Switched from Declared or Intended Majors by 1991, for 810,794 Undergraduates who Entered a National Sample of Four-Year Institutions in 1987.

*Based on unpublished tabulations provided by the Cooperative Institutional Research Program, Higher Education Research Institute, University of California, Los Angeles, April 1993.*

M=Male, F=Female, N/A= Not Available

| *Original major* | *% Stayed in same major* | | *% Moved to major in same group* | | *% Stayed in major or group* | | *% Switched to other group of majors* | |
|---|---|---|---|---|---|---|---|---|
| | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* |
| Biological Sciences | 47.1 | 35.8 | 6.6 | 7.5 | 53.8 | 43.3 | 46.2 | 56.7 |
| Physical Sciences | 30.6 | 27.7 | 15.9 | 28.1 | 46.5 | 55.7 | 53.5 | 44.3 |
| Engineering | 51.5 | 50.8 | 10.2 | 12.1 | 61.7 | 62.9 | 38.3 | 37.1 |
| Mathematics/ Statistics | 39.9 | 27.8 | 6.2 | N/A | 46.1 | 27.8 | 53.9 | 72.3 |
| Agriculture | N/A | 20.9 | N/A | N/A | N/A | 20.9 | N/A | 79.1 |
| *All S.M.E. Majors* | *49.0* | *37.7* | *9.8* | *10.0* | *58.8* | *47.6* | *41.2* | *52.4* |
| History/ Political Science | 62.0 | 31.3 | 25.5 | 19.2 | 87.5 | 50.5 | 12.5 | 49.5 |
| Social Sciences | 64.4 | 52.5 | 18.9 | 14.8 | 83.3 | 67.3 | 16.7 | 32.7 |
| Fine Arts | 48.1 | 53.2 | 16.7 | 22.4 | 64.8 | 76.7 | 35.2 | 24.3 |
| English | 57.2 | 56.2 | 26.9 | 29.1 | 84.1 | 85.3 | 15.9 | 14.1 |
| Other Humanities | 30.5 | 27.8 | 46.2 | 37.5 | 76.6 | 65.3 | 23.4 | 34.7 |
| *All Humanities/ Social Sciences* | *54.7* | *44.0* | *23.2* | *20.7* | *77.9* | *64.7* | *22.1* | *35.3* |
| Health Professions | 11.8 | 39.3 | - | - | 11.8 | 39.3 | 88.2 | 60.7 |
| Computer Science/ Technical | 54.2 | 30.8 | - | - | 54.2 | 30.8 | 45.8 | 69.2 |
| Business | 61.8 | 56.7 | - | - | 61.8 | 56.7 | 38.2 | 43.3 |
| Education | 44.7 | 73.1 | - | - | 44.8 | 73.1 | 55.3 | 26.9 |
| Other Non-Technical | 48.7 | 30.1 | - | - | 48.7 | 30.7 | 51.3 | 69.3 |

TABLE 1.4 Of those who Persisted in and Switched from Declared or Intended Majors by 1991, Percent who were Men and Percent who were Women among 810,794 Undergraduates who Entered a National Sample of Four-Year Institutions in 1987.

***Based on unpublished tabulations provided by the Cooperative Institutional Research Program, Higher Education Research Institute, University of California, Los Angeles, April 1993.***

**M=Male, F=Female, N/A= Not Available**

| *Original major* | *Of all who stayed in same major, % who were* | | *Of all who moved to major in same group, % who were* | | *Of all who stayed in major or group, % who were* | | *Of all who switched to other group of majors, % who were* | |
|---|---|---|---|---|---|---|---|---|
| | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* |
| Biological Sciences | 61.5 | 38.5 | 51.8 | 48.2 | 60.1 | 39.9 | 49.8 | 50.2 |
| Physical Sciences | 77.0 | 23.0 | 63.1 | 36.9 | 71.6 | 28.4 | 78.5 | 21.5 |
| Engineering | 86.0 | 14.0 | 83.7 | 16.3 | 85.6 | 14.4 | 86.2 | 13.8 |
| Mathematics/ Statistics | 61.2 | 38.8 | N/A | N/A | 64.5 | 35.5 | 45.0 | 55.0 |
| Agriculture | 76.4 | 23.6 | N/A | N/A | 76.4 | 23.6 | N/A | N/A |
| *All S.M.E. Majors* | *78.4* | *21.6* | *73.6* | *26.4* | *77.6* | *22.4* | *68.8* | *31.2* |
| History/ Political Science | 56.6 | 43.4 | 46.7 | 53.3 | 53.3 | 46.7 | 14.2 | 85.8 |
| Social Sciences | 33.6 | 66.4 | 34.4 | 65.6 | 33.8 | 66.2 | 17.4 | 82.6 |
| Fine Arts | 49.3 | 50.7 | 44.5 | 55.6 | 48.0 | 52.0 | 60.9 | 39.1 |
| English | 34.0 | 66.0 | 31.0 | 69.0 | 33.3 | 66.7 | 35.4 | 64.6 |
| Other Humanities | 33.8 | 66.2 | 36.5 | 63.5 | 35.4 | 64.6 | 23.9 | 76.1 |
| *All Humanities/ Social Sciences* | *43.4* | *56.6* | *40.9* | *59.1* | *42.7* | *57.3* | *27.9* | *72.1* |
| Health Professions | 14.5 | 85.5 | - | - | 12.7 | 74.7 | 45.0 | 55.0 |
| Computer Science/ Technical | 77.9 | 22.1 | - | - | 77.9 | 22.1 | 57.0 | 43.0 |
| Business | 57.0 | 43.0 | - | - | 57.0 | 43.0 | 51.8 | 48.2 |
| Education | 12.6 | 87.4 | - | - | 12.6 | 87.4 | 32.6 | 67.4 |
| Other Non-Technical | 50.5 | 49.5 | - | - | 50.5 | 49.5 | 32.2 | 67.8 |

TABLE 1.5 Final Major Choices by 1991 of 142,890 Male and Female Undergraduate Switchers Entering S.M.E. Majors in a National Sample of Four-Year Institutions in 1987.

*Based on unpublished tabulations provided by the Cooperative Institutional Research Program, Higher Education Research Institute, University of California, Los Angeles, April 1993.*

M=Male, F=Female

| *Original S.M.E. Majors* | *Non-S.M.E. Destination Majors of S.M.E. Switchers* | | | | | | | | | | | | *Totals by Major* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Computer Science* | | *Health* | | *Business* | | *Education* | | *Humanities & Fine Arts* | | *Other Non-Technical* | | | |
| | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* | *M* | *F* |
| *Mathematics/ Statistics* | 24.4 | 2.0 | 0.0 | 5.0 | 9.4 | 12.5 | 8.5 | 45.2 | 33.6 | 32.0 | 24.0 | 3.3 | 99.9 | 100.0 |
| *Physical Sciences* | 0.0 | 4.0 | 1.5 | 17.8 | 5.3 | 10.5 | 1.8 | 10.0 | 47.0 | 57.8 | 44.4 | 0.0 | 100.0 | 100.1 |
| *Biological Sciences* | 39.3 | 1.1 | 1.9 | 2.6 | 8.4 | 6.0 | 1.1 | 19.7 | 39.9 | 57.1 | 9.4 | 13.6 | 100.0 | 100.1 |
| *Engineering* | 18.9 | 9.0 | 3.2 | 0.0 | 39.1 | 21.4 | 2.2 | 15.5 | 28.1 | 42.0 | 8.5 | 12.1 | 100.0 | 100.0 |
| *Totals: S.M.E to Non-S.M.E Majors* | *20.7* | *3.4* | *2.6* | *3.7* | *26.4* | *10.9* | *2.0* | *20.5* | *33.2* | *50.8* | *14.1* | *10.7* | *99.0* | *100.0* |

faculty, or the wider community see as traditional male provinces. Among those whose first choice lies in the humanities and social sciences, women also exhibit (to a higher degree than do men) the liberal arts tradition of 'trying out' different majors before settling into a final choice. The C.I.R.P. data also show young women exercising a greater degree of liberty to change their minds across a broad spectrum of majors. These data also suggest the dominance of conservatism in the field choices of women. The majors in which women show strongest adherence to their original choice are those in which they have a longer tradition of academic involvement, career access, or professional dominance, namely, education, the fine arts, the humanities and English.[9] Women who choose one of these majors are much more likely to remain in it. S.M.E. majors are a less-traditional choice, and women show much less persistence in these than in more traditional majors. Not only do women enter these majors in lower proportions than men, they also leave them in higher proportions. To enter S.M.E. majors at all, women must resist traditionalist pressures. They will be supported or encouraged by the same conservative pressures to leave an S.M.E. major for something more traditional. The final field choice of women who initially chose (non-traditional) S.M.E. majors tends to be conservative.

We are greatly indebted to the Higher Education Research Institute, U.C.L.A., for enabling us to set S.M.E. switching patterns within the wider context of persistence and switching across all majors, and to distinguish the field choice patterns of women from those of men.

## Method of Inquiry

Our research design for this study was ethnographic. It's purpose was to derive from students' reflections on their undergraduate experiences a set of testable hypotheses which address our research questions. This method differs from deductive research which tests hypotheses derived from prior studies or speculation. The study was conducted over a three-year period (1990-1993) with 335 students at seven four-year institutions of different type and location. Approximately 75 percent of the data were gathered by personal interviews and the remaining 25 percent in focus groups of three to five members. An additional 125 students (i.e., 460 in total) took part in focus group discussions on six other campuses. Their purpose was to check the validity of our tentative hypotheses. Interviews varied in length from 45 to 75 minutes and focus groups from 90 minutes to two and a half hours. The verbatim transcriptions and field notes from all interviews and focus groups yielded a data set of over 600 interview hours. All interviews and focus groups were conducted in the manner of semi-structured conversations that focused on students' experiences in science, mathematics, or engineering classes, and in other contexts (e.g., high school) with relevance for their decisions to enter, continue in, or leave their original S.M.E. majors. The form and content of interviews was focused upon discovering what factors (whether present or absent) had bearing for S.M.E. attrition and persistence, and what were their patterns of interaction and relative importance.

We asked the institutional records departments of the participating institutions to randomly generate lists of potential informants who, *prima facie*, met our requirements for interview. We included as 'science': the biological sciences (biology, biochemistry, microbiology, botany, zoology and animal science); the physical sciences (astronomy, physics, chemistry, earth science/geology). Mathematics and applied mathematics majors were drawn along with science majors so that, taken together, they represented half of our sample. Engineering majors comprised the other half of the sample, and included aerospace, civil, chemical, electrical, industrial/design, mechanical, environmental and general engineering. Participating institutions were asked to draw approximately twice as many potential interviewees as we ultimately selected for interview, and to provide information on each student's sex, ethnicity, current major, former major (where applicable), year in school, S.A.T. score in mathematics (or equivalent) and local telephone number. We subsequently checked the accuracy of this information with each potential interviewee in a short telephone conversation.

All of the students selected were those who had a mathematics S.A.T. (or equivalent) score of 650 or higher. This performance criterion was chosen on the advice of S.M.E. faculty so as to include in our sample only those students whom they expected to be capable of handling the course work. In order to put the accounts of switchers into context, it was also important to have the perspectives of non-switchers. The sample of 335 undergraduates was designed to include slightly more switchers (54.6%) than non-switchers (45.4%).[10] All switchers were either juniors or seniors and all non-switchers were S.M.E. seniors who were close to graduation.[11] In order to clarify what distinguishes the experiences of male S.M.E. students of color, and all women, from those of their white male peers, and how these differences bear upon their higher rates of attrition, we deliberately over-sampled these groups who, historically, have been under-represented in S.M.E. majors: 52 percent of the sample of white students were women, and 48 percent were men; 88 students of color (46 women and 42 men) were interviewed (26 percent of the total sample).[12] The groups represented were: Hispanic, Latino/Latina and Chicano/Chicana; black; native American and Asian-American (whose ancestries were Japanese, Chinese, Laotian, Cambodian, Filipino, Korean, East Indian and Pakistani). We selected only American-born students in order to compare experiences in U.S. high schools. The composition of focus groups was based on shared characteristics such as sex, type of major, and switcher or non-switcher status. With rare exceptions, we found it more productive to interview students of color individually.

As our purpose was to discover as many factors bearing upon attrition and persistence as our panel of expert witnesses could offer, the use of standardized interview instruments was precluded. During the brief screening interviews (by telephone) we explained the purpose of the study. Those we selected, and who agreed to take part, were invited (prior to their interview or group discussion) to think about factors which had shaped their decisions. Interviews and focus groups were conducted in the manner of a focused conversation: issues from an initial topic outline were explored in an order dictated by the natural structure of the discussion, and those not spontaneously mentioned were raised at natural breaks in the conversation. New issues brought up by participants pertinent to the main research questions were always pursued. Thus, from the outset, our tentative set of discussion questions was continuously refined and augmented by the emphases which informants placed on the factors they discussed. As important new themes emerged, they were explored with all subsequent interviewees.[13]

Some basic information was collected from every student: current and former majors; year in school; mathematics S.A.T. scores, high school and college G.P.A.s; evaluation of high school preparation for S.M.E. classes; and reasons for their initial choice of a major. We asked all participants for a profile of their high school and college grades (their mathematics S.A.T. scores having been provided in advance by their institution). However, restrictions on the disclosure of students records, as well as the difficulty of working with unfamiliar institutional data sets, precluded our collection of other than self-reported data. In addition, all women and male students of color were asked to comment on factors which they felt distinguished their experiences from those of white male peers. Conversely, all white males were asked about any differences they had noticed between their own experiences and those of the female and male students of color who shared their classes. Everyone was asked to describe any differences they had noticed in the nature, difficulty, and teaching styles of S.M.E. and non-S.M.E. classes. Switchers were asked to reflect on the process of deciding to change majors. Non-switchers were invited to describe issues bearing on their own persistence, and to offer explanations for the loss of peers to other majors. We explored the personal strategies and institutional programs which had aided the persistence of non-switchers, and asked all students to discuss their experiences with the advisory systems—both departmental and institutional. Finally, we asked every participant to offer advice to their departments, colleges and schools on how the education they had experienced could be improved, and how more students who were able and interested might be retained.

The study took place on seven campuses in four different geographic areas.[14] Institutions were selected on the basis of their funding (public or private), their mission, the level of prestige accorded their research activities, and the size and composition of their graduate and undergraduate populations.

The scheme used to differentiate types of four-year institutions was a modified version of the Carnegie classification.[15] Our concentration on institutions in which the majority of undergraduates receive their S.M.E. education precluded the choice of historically black or women's colleges, and institutions with highly specialized missions. We are aware, however, that important insights into persistence and attrition within these majors are to be gained by inquiries which focus on these more specialized institutions.[16]

The three private institutions included in our sample were:

* a small liberal arts college in the West with a strong reputation for its teaching (engineering is not offered)

* a city-based university also in the West, with a small student body (under 5,000) and faculty focus on teaching rather than funded research. This institution offers an undergraduate degree in engineering, and awards master's degrees and doctorates in mathematics and science

* a large university on the West Coast with a highly selective admissions policy, and a high degree of prestige related to its research-generating faculty

The four public universities selected vary in terms of the prestige accorded their funded research in science and engineering. They were:

* a multi-role urban university in the Northeast with large enrollments in undergraduate science, mathematics and engineering, but lacking an established reputation or strong funding for its science and engineering research

* a large urban university in the Midwest which is well-funded by research grants, particularly in the field of engineering, and with an annual production of Ph.D.s and a prestige ranking for its research which are similar to that of the leading private research university selected

* a state university in the West with well-established graduate programs in science, mathematics and engineering, and a prestigious, highly-funded research program in engineering. Originally a land-grant college, it has an applied science emphasis, a fairly open admissions policy and a large student intake from working-class families

* a large state university which is considered the 'flagship' institution for its western state, and has a good reputation for its engineering school and high prestige for several of its science departments

Each of the five large universities in our sample offers graduate degrees in science, mathematics and engineering, has large undergraduate enrollments, and a diverse student population. One-third of our interviewees (N=112) attended the private institutions in our sample, and two-thirds (N=223) attended the large public universities. Overall, the institutions we selected can be ranked along a continuum of prestige that takes into account research funding and the number of graduate degrees awarded.

It was our concern to interview sufficient numbers of students in particular racial or ethnic groups to get a clear picture of their distinctive concerns. Therefore, our final choice of locations and institutional types was also informed by the racial/ethnic composition of each potential study site. Thus, at the midwestern university, the predominant ethnic minority group was Asian, many of whom were the children of either first- or second-generation Indo-Chinese refugees. The northeastern university enrolled more black students than are to be found in the western or midwestern institutions. Students in the Northeast who were Hispanic had ties to Puerto Rico or South America, rather than (as in the west) Mexico. At the private university on the West Coast, Asian-American students were not numerically a minority. However, on the western campus, most Asian students were foreign-born and had received their high school education overseas. Our supposition that regional differences in the composition of minority populations (whether on campus, or living in the vicinity of the institution) make important differences in the way that S.M.E. education is experienced by students of differing races or ethnicities was, subsequently, borne out by our findings, and is discussed in Chapter 6.

In order to retain site confidentially, we will use the following abbreviations to indicate the location and prestige ranking of particular institutions in the text, and in tables and figures:

* WCPRI1 = West Coast, private, ranking 1
* WPRI2 = western, private, ranking 2
* WPRI3 = western, private, ranking 3
* MWPUB1 = midwestern, public, ranking 1
* WPUB2 = western, public, ranking 2
* WPUB3 = western, public, ranking 3
* ECPUB4 = East Coast, public, ranking 4

### *Additional Data and Validity Checks*

All ethnography is iterative. Data coding and analysis begin with the transcription of the first set of interviews and continue throughout the study. As dominant themes, then hypotheses, begin to emerge, investigators return to the field to check the validity of their tentative theoretical constructs among comparable groups of informants. Over the three years of this study, invitations to discuss our work at institutions which either parallelled or augmented our set of seven institutional types and four geographic settings, offered the opportunity to conduct additional focus groups with 125 students on six extra campuses. The total number of students interviewed was, thus, 460. This second round of interviewing gave us feed-back, clarification and additional information. It also allowed us to discuss the hypotheses derived from the main site data with students at similar institutions, and to augment our understanding of student experiences in a wider range of institutions and settings. In these discussions, students corroborated our findings from the seven main sites, and thus insure the reliability and validity of the work overall.

Both during site visits, and in presentation of findings on other campuses, we continually discussed the issues raised by our research questions and our emergent findings with deans, faculty, administrators, advisors, special program directors and S.M.E. graduate students. They were a valuable source of information on the structure of particular majors, the cultural climate of campuses, departments and colleges, the local economy, initiatives taken to address aspects of S.M.E. recruitment and retention and the difficulties associated with seeking to bring about change.

### *Method of Ethnographic Data Analysis*

The tape-recordings of interviews and focus groups were transcribed verbatim into a word processing program and submitted to 'The Ethnograph',[17] a set of computer programs which allow for the multiple, overlapping and nested coding of a large volume of transcribed documents to a high degree of complexity. Each line-numbered transcript was searched for information bearing upon student attrition. Most commonly, information was embedded in narrative accounts of student experiences rather than offered in abstract statements. This allowed individual transcripts to be checked for internal consistency between the opinions or explanations offered by participants, their descriptions of events, and the reflections and feelings they evoked. Lines or segments referencing problems of different type and importance were tagged by code names. There were no preconceived codes: each new code name referenced a discrete idea not previously raised. Because answers to the same question were often not of the same character and did not cover the same issues, codes were never developed on the basis of the questions asked, but always by the nature of the responses, and by spontaneously-offered comments, narratives and illustrations. Because participants often made several points in the same statement, segments were often indexed by several different codes, each with a different name. Groups of codes which clustered around particular themes were given domain names, and the whole branching and inter-connected structure of codes and domains was gradually built into a code book which, at any point in time, represented the state of analysis.

Descriptions of the problems experienced by both switchers and non-switchers were coded in separate domains from those identified as having directly contributed to decisions to leave the sciences. Students' theories about switching which were based on observation were also coded separately from those grounded in personal experience. The number of participants who mentioned each issue was counted across the whole data set and for particular groups within it. Student concerns about their S.M.E. majors are expressed in terms of the number of people who mentioned each issue. Throughout our account, we have followed the ethnographic tradition of presenting our analysis through the accounts of the participants themselves.

## Overview of Findings

Perhaps the most important single generalization arising from our analysis is that we did not find switchers and non-switchers to be two different kinds of people. That is to say, we did not find them to differ by individual attributes of performance, attitude, or behavior, to any degree sufficient to explain why one group left, and the other group stayed. Rather, we found a similar array of abilities, motivations and study-related behaviors distributed across the entire sample. We also found the most common reasons for switching arose from a set of problems which, to varying degrees, were shared by switchers and non-switchers alike. What distinguished the survivors from those who left was the development of particular attitudes or coping strategies—both legitimate and illegitimate. Serendipity also played a part in persistence, often in the form of intervention by faculty at a critical point in the student's academic or personal life.

In reflecting on their experiences in the first two years of S.M.E. majors, switchers invariably distinguished experiences they perceived as bearing directly on their decision to leave S.M.E. majors, and problems of lesser significance which they needed to accommodate, tolerate, or resolve, in order to stay. Exactly the same kinds of problems prompted some undergraduates to switch majors, were an additional source of stress to students who switched for other reasons, and were troublesome to many who remained in their major. Non-switchers expressed the same kinds of concerns and reservations about their majors as did switchers. With some types of problems, switchers and non-switchers differed little in the proportion of each group who had experienced them. With other problems, non-switchers either experienced them less, or had learned to cope with them better, than had the switchers.

On every campus, we also found a small group of S.M.E. seniors who reported they were planning non-S.M.E. careers following graduation. These post-graduate switchers were 16.5 percent of all seniors when all seven campuses were taken into account.

The issues and concerns of switchers and non-switchers focused around the same set of issues across all seven campuses: there were no major differences between institutions of different type in the nature of the problems described by their students. Although there was some variation in the ranking of problems by institutional type, every category of problem was found on every campus, regardless of differences in size, mission, funding, selectivity, or reputation, and there was little differentiation across campuses in identification of the most serious concerns by either switchers or non-switchers.

Overall, the issues raised by our participants fell into 23 categories, some of which are broader than others. There is, necessarily, some overlap in the boundaries between problem categories because, as a normal matter, people see their concerns as essentially interrelated. Also the ways in which undergraduates define or categorize concerns which they perceive as relevant to attrition or persistence do not necessarily square with the ways in which the causes of attrition are conceptualized by others, including faculty. Throughout our analyses, we followed our informants' definitions and distinctions in assigning significance to their experiences. We have found it useful to represent the relative significance of issues arising from accounts of S.M.E. undergraduate experiences using the metaphor of an 'iceberg'. This idea is intended to convey our most important single finding that problems which contribute most to field switching are set within a group of related concerns which are experienced, to some degree, by all S.M.E. students, whether they leave or whether they stay. Those who switch represent only the tip of a much larger problem. As, apart from those few participants who shared any particular focus group, none of the interviewees knew what any other participant had told us, there was a high degree of concurrence across the whole sample as to the salient issues, and their relative significance for attrition. The iceberg metaphor is employed in this chapter in Tables 1.6, 1.8 and 1.9, and in Chapter 5 (Tables 5.1 and 5.2 ), both as a way to summarize findings, and in order to compare the relative importance that sub-sets of informants (by sex and type of major) assigned to particular issues.[18] In each table, the first column contains all factors cited by S.M.E. switchers as having directly contributed to their switching decision. Each issue for each switcher is counted only once, although switchers often returned more than once to concerns which had considerable emotional significance for them.[19] Switching decisions were never the result of a single, overwhelming concern; they were always the upshot of a 'push and pull' process over time. This process typically involved reactions to problems with S.M.E. majors, concerns about S.M.E. careers, and the perceived merits of academic or career alternatives. The average number of factors contributing to each switching decision was 4.2.

The second column in each of the 'iceberg' tables includes all the decision-related concerns reflected in the first column, plus mentions of the same issue by other switchers, whether or not they had significance for switching decisions. This information is especially useful for comparison with the third column, which represents the proportions of non-switchers who mentioned each kind of concern as an aspect of their personal experience. Non-switchers mentioned an average of 5.4 concerns, compared with an average of 8.6 for switchers. Thus, one simple (though not especially illuminating) way to distinguish switchers from non-switchers is to see them as people who have rather more problems with their original majors than do non-switchers. The final column shows the proportion of the whole sample who mentioned each type of concern. We feel the information in this column might act as a guide for those deliberating what aspects of S.M.E. education might usefully be changed, whether or not their primary consideration is attrition.

Contrary to the common assumption that most switching is caused by personal inadequacy in the face of academic challenge, one strong finding reflected in Table 1.6 is the high proportion of factors cited as significant in switching decisions which arise either from structural or cultural sources within institutions, or from students' concerns about their career prospects. We also found strong similarity between the concerns of switchers and non-switchers in almost half of all the issues represented in Table 1.6: the four most commonly cited concerns leading to switching decisions were also cited as concerns by between 31 percent and 74 percent of non-switchers. Ranked according to the contribution which they make to switching, these are:

* lack or loss of interest in science
* belief that a non-S.M.E. major holds more interest, or offers a better education
* poor teaching by S.M.E. faculty
* feeling overwhelmed by the pace and load of curriculum demands

Seven issues were cited as shared concerns by more than one-third of both switchers and non-switchers. They include the four listed above, plus (by rank):

* choosing an S.M.E. major for reasons that prove inappropriate
* inadequate departmental or institutional provisions for advising or counseling about academic, career, or personal concerns
* inadequate high school preparation, in terms of disciplinary content or depth, conceptual grasp, or study skills

An additional four concerns were shared by a smaller proportion (20-30%) of all switchers and non-switchers. In rank order they are:

* financial difficulty in completing S.M.E. majors
* conceptual difficulties with one or more S.M.E. subject(s)
* the unexpected length of S.M.E. majors (i.e. more than four years)
* language difficulties with foreign faculty or T.A.s.

TABLE 1.6 "The Problem Iceberg." Factors Contributing to All Switching Decisions, and to the Concerns of Switchers, of Non-Switchers and of All Students (N=335).

| *Issue* | *Factor in switching decisions (%)* | *All switchers' concerns (%)* | *All non-switchers' concerns (%)* | *All students' concerns (%)* |
|---|---|---|---|---|
| Lack of/loss of interest in SME: "turned off science" | 43 | 60 | 36 | 49 |
| Non-SME major offers better education/more interest. | 40 | 58 | 32 | 46 |
| Poor teaching by SME faculty | 36 | 90 | 74 | 83 |
| Curriculum overload, fast pace overwhelming | 35 | 45 | 41 | 44 |
| SME career options/rewards felt not worth effort to get degree | 31 | 43 | 20 | 33 |
| Rejection of SME careers and associated lifestyles | 29 | 43 | 21 | 33 |
| Shift to more appealing non-S.M.E.career option | 27 | 33 | 16* | 25 |
| Inadequate advising or help with academic problems | 24 | 75 | 52 | 65 |
| Discouraged/lost confidence due to low grades in early years | 23 | 34 | 12 | 24 |
| Financial problems of completing S.M.E. majors | 17 | 30 | 23 | 27 |
| Inadequate high school preparation in subjects/study skills | 15 | 40 | 38 | 39 |
| Morale undermined by competitive SME culture | 15 | 28 | 9 | 20 |
| Reasons for choice of SME major prove inappropriate | 14 | 82 | 40 | 63 |
| Conceptual difficulties with one or more S.M.E. subject(s) | 13 | 27 | 25 | 26 |
| Lack of peer study group support | 12 | 17 | 7 | 12 |
| Discovery of aptitude for non-S.M.E. subject | 10 | 12 | 5 | 8 |
| Prefer teaching approach in non-S.M.E. courses | 9 | 24 | 15 | 20 |
| Unexpected length of S.M.E. degree: more than four years | 9 | 20 | 28 | 24 |
| Switching as means to career goal: system playing | 7 | 9 | 3 | 6 |
| Language difficulties with foreign faculty or T.A.s | 3 | 30 | 20 | 25 |
| Problems related to class size | 0 | 20 | 11 | 16 |
| Poor teaching, lab, or recitation support by T.A.s | 0 | 20 | 11 | 16 |
| Poor lab/computer lab facilities | 0 | 4 | 4 | 4 |

*Issue raised by non-switchers intending to move into non-S.M.E. field following graduation.

Only four issues which contributed to switching decisions were *not* substantially shared with non-switchers. Three of these reflect underlying concerns about career prospects: that the perceived job options, or material rewards, of S.M.E. careers are not worth the effort required to complete an S.M.E. degree; perceptions of low job satisfaction and/or unappealing lifestyles in S.M.E. careers; and that careers in non-S.M.E. fields have greater appeal. The fourth issue in this group reflects students' experiences of low grades and of curve-grading in their first two years, leading to discouragement, and loss of confidence in their ability to do mathematics and science.

It would be hard to argue on the basis of this evidence, either that switchers suffer from a distinctive set of problems, or that switchers differ in salient ways from non-switchers as individuals. All of the most commonly-mentioned problems of switchers and non-switchers, including those which contribute most to switching decisions, imply criticisms of the practices and attitudes which define and sustain the structure and culture of S.M.E. majors. The economic difficulties cited by switchers, and to a lesser degree by non-switchers, reflect a shared high level of anxiety about career and lifestyle prospects at a time of economic uncertainty, and about the level of satisfaction that careers open to those with S.M.E. qualifications are likely to offer. Expressions of anxiety about career and lifestyle prospects increased over the three years of interviewing. Job-related concerns were more highly ranked by undergraduates interviewed at the last three campuses than at the first four campuses reported on in 1991.

Criticisms of faculty pedagogy contributed to one-third (36.1%) of all switching decisions, and were the third most commonly-mentioned factor in such decisions. However, complaints about poor teaching were almost universal among switchers (90.2%), and were the most commonly-cited type of complaint among non-switchers (73.7%). Complaints about pedagogy cannot, however, be seen in isolation. All of the four most highly-ranked factors contributing to switching decisions reflect some aspect of teaching, or rate the quality of learning experiences offered by S.M.E. faculty as poor, compared with those offered by former high school science teachers, and/or faculty in non-S.M.E. disciplines. The significance of this factor does not end here. In one way or another, concerns about S.M.E. faculty teaching, advising, assessment practices and curriculum design, pervade all but seven of the 23 issues represented in our 'iceberg' tables. Thus:

* The rejection of S.M.E. careers or lifestyles is partly a rejection of the role models which S.M.E. faculty and graduate students present to undergraduates
* S.M.E. faculty are often represented as 'unapproachable' or unavailable for help with either academic or career-planning concerns

* Students perceive the curve-grading systems widely employed by S.M.E. faculty as reflecting disdain for the worth or potential of most under-classmen. Their presumed purpose is to drive a high proportion of students away, rather than give realistic and useful feedback to students on their level of understanding, or conceptual progress
* Harsh grading systems, which are part of a traditional competitive S.M.E. culture, also preclude or discourage collaborative learning strategies, which many students view as critical to a good understanding of the material, and to a deeper appreciation of concepts and their application
* The experience of conceptual difficulty at particular points in particular classes, which might not constitute an insuperable barrier to progress if addressed in a timely way, commonly sets in motion a downward spiral of falling confidence, reduced class attendance, falling grades, and despair—leading to exit from the major
* T.A.s (whether American or foreign) bear a disproportionate responsibility for the teaching of fundamental material in basic S.M.E. classes that are over-enrolled given the pedagogical resources available
* Over-packed curricula which lengthen the time needed to complete an S.M.E. degree place extra financial burdens on the growing proportion of students who must pay for their education by employment or the accumulation of debt. Seniors express the suspicion that over-packing the syllabi of basic classes is maintained for 'weed-out', rather than for pedagogical, purposes
* Curriculum overload (combined with the growing length and costs of S.M.E. majors), also supports the perception that the rewards (both material and personal) of S.M.E.-based careers are not worth the effort and costs required to secure them

Thus, criticisms of faculty pedagogy, together with those of curriculum design and student assessment practices, constitute the largest group of problems in 'the iceberg,' both for switchers and non-switchers.

### *The Loss of Able Students from S.M.E. Majors*

The theory that switchers can be distinguished from non-switchers by their inability to cope with the intrinsic 'hardness' of S.M.E. majors, or their unwillingness to commit to sufficient hard work, is a traditional way of explaining attrition rates and reflects a disinclination to see attrition as 'a problem.' It may also function as a barrier to attempts to address the concerns of students who persist, as well as those who leave. In Chapter 3, we discuss what the 'hardness' of science means to students, and how it shapes their attitudes and behavior. Here we draw attention to the similarities between switchers and non-switching seniors which support our assertion that, on the basis of individual attributes (including academic performance) it is difficult to predict which students are likely to stay, and which to leave.

First, as Table 1.6 indicates, we found a strong similarity between the proportions of switchers and non-switchers who reported conceptual difficulties in one or more S.M.E. subject(s) (i.e., 26.8 percent of all switchers and 25.0 percent of non-switchers). As a factor in decisions to leave S.M.E. majors, conceptual difficulties were reported by a comparatively small proportion of switchers (12.6%) and ranked 14th out of 23 contributory concerns. Non-switchers suffered in similar proportions to switchers from the consequences of high school preparation which they subsequently found to be inadequate for college-level mathematics or science: 40.4 percent of all switchers and 37.5 percent of non-switchers reported inadequate high school preparation. This deficiency was an important basic problem for many students, despite the apparent competence in mathematics indicated by their S.A.T. scores of 650 or more. However, conceptual difficulty was thought less important than 10 other concerns as a final consideration in switching decisions. Where conceptual problems were a factor in switching decisions studefits, reported that difficulty with aspects of a single subject (predominantly in mathematics or chemistry) most commonly acted as a barrier to further progress.

One-quarter (24.0%) of switchers described difficulty in getting help from faculty and/or T.A.s as having contributed to their decision to leave. However, 75.4 percent of all switchers, and 52.0 percent of non-switchers also described this problem. More switchers (16.9%) than non-switchers (7.2%) reported they had not worked with peer study groups to gain a better grasp of material they found difficult. With hindsight, 11.5 percent of switchers considered this omission to have contributed to their leaving.

Though we did encounter switchers who were unwilling to undertake the heavy work demands and fierce pace of introductory classes, we also found indications that most switchers had worked hard in S.M.E. classes and had invested considerable time, money, and personal commitment in their effort to persist. Earlier in this chapter, we cited national studies which document the higher demonstrated ability of freshmen entering S.M.E. than those entering non-S.M.E., majors. To this, we add our finding that the mean of G.P.A.s reported by switchers just prior to leaving S.M.E. majors was, at 3.0 (range: 1.9 - 3.85) not dramatically lower than the mean of current G.P.A.s (3.15; range: 2.95 - 3.95) reported by non-switching seniors. There were some variations by discipline: the mean exit G.P.A. for engineering switchers was 2.85 (range: 1.9 - 3.65), and the current G.P.A. for seniors was 3.5 (range: 2.95 - 3.95). The mean exit G.P.A. for science and mathematics switchers was 3.3 (range: 2.0 - 3.85), and the current G.P.A. for seniors was 3.2 (range: 3.0 - 3.95). This finding, based on the self-reported scores of our informants, closely follows that of a recent (1992) study of switchers and persisters at the College of Engineering, the University of California at Berkeley.[20] Humphreys and Freeland's study, which examined all first-time engineering freshmen entering in the fall semesters of 1985, 1986, and 1987, found that, "students who persisted and students who switched earned comparable grade point averages (3.10 as compared with 3.07)" (p. 5). This difference was not found to be statistically significant. Engineering switchers were also found to have entered with higher verbal S.A.T. scores than did persisters. The authors note that "students who achieved well academically, both in high school and in the College of Engineering at the freshman level, may choose to switch nevertheless" (p. 5). Our finding is also supported by data provided by the University of Colorado at Boulder, for freshmen who entered S.M.E. majors between 1980 and 1988.[21] The average predicted G.P.A. (P.G.P.A.) for those who persisted was (at 2.93) only slightly higher than for switchers (2.86). Comparison by gender revealed that women entered with higher average P.G.P.A. scores than men (i.e., 3.05, compared with 2.99 in engineering, and 2.84, compared with 2.72 in science and mathematics). Although women entering S.M.E. majors are, in national samples, found to have higher proportionate rates of switching than men, in this analysis, both the women who persisted and those who switched had higher average P.G.P.A. scores than male persisters and male switchers respectively (i.e., 2.95 compared with 2.92 for persisters, and 2.88 compared with 2.84 for switchers).

We were also impressed by the length of time switchers pursued their original intention before finally deciding to leave. The average time period spent in the major before leaving it was, for engineering switchers, 2.6 years (range: 1 - 4 years), and for science and mathematics switchers, 2.1 years (range: 1 - 3 years). This finding underscores our observation from the text data that, for most students, the decision to switch was not taken until they had already expended a considerable amount of time, money and effort in persistence.

Both the accounts of switchers, and those of non-switchers who describe the experiences of room-mates and friends, also offer powerful testimony of the desire to persist, and the efforts made to do so:

> I do work hard, and my average load over these four years—even when I was transferring out—has been 17, 18 hours a semester, plus a couple of night classes sometimes. It doesn't really bother me to work that hard. But when it's a concept I don't understand and I go to get some kind of help from faculty and they just don't give it, that's discouraging. (Male white engineering switcher)

> She was one of those people who all they did was study...Her freshman year, we had to *beg* her not to spend all her time working...I don't think she took a class that wasn't biology or science...And now she's a psychology major. She just got so burnt out. She was pushing herself so hard, and she just wasn't enjoying it. (Female black science non-switcher)

> I tried for all these courses. I've thought about just devoting every ounce of my life, but I don't know if that's possible. But that's what I would think about. This Christmas, I went home with my chemistry book and read nine chapters, but when I came back here, I started failing the tests and I just got more and more upset. (Male native American science switcher)

> I'd go home and I would cram and study all night long. And the next day, the teacher might take two steps backwards and perhaps cover a tiny bit of what you covered the day before. But in engineering, there's absolutely no time for any falling back. In fact they're always way ahead of where you think you should be. It was just push, push, push—all the time. That's why I kept on pushing myself. I thought, 'I'm just not pushing myself hard enough.' All my friends were dropping out. (Male Asian-American engineering switcher)

We found many switchers whose level of ability and application should have been sufficient, given a more encouraging learning environment, for them to complete their major. We also encountered a smaller number of multi-talented switchers, the loss of whose high abilities from science-based fields may be of particular concern.[22] Both switchers and non-switchers saw their S.M.E. majors as prone to lose students who had both sufficient ability and interest to complete the degree:

> What bothers me is the number of people who know what engineering is about, and really have the capability to do well and be good in the field, but end up going a different way for reasons other than lack of ability. (Female white engineering non-switcher)

> You could say to them, 'Do you realize that you're pushing talented people away from your major?' (Male white science switcher)

> Well, since I've been here, I've gotten As or B+s, so I've done well in math classes here—same with high school—I always got As in high school. (Female white engineering switcher)

> I did one of the 200-level Calc III classes in freshman year, just on the side. It was fine—well, actually it was a bit boring because I'd done all of that in high school. (Male white science switcher)

> I love the field work, and that's what I would really like to do. I like to think about what's happening, and form theories about it...I got an A in biology. I got an A in chemistry too. (Male native American science switcher)

> My G.P.A. has hung right around 3.7 and only went as low as 3.6 in my first block. My physics courses were Bs or B+s, and the math was, I think, A-. (Male white science switcher, entering graduate school in music)

Student explanations for this 'wastage' stressed the counter-productive consequences of faculty's preoccupation with weeding-out, rather than supporting and encouraging, students:

I've friends who were in physics and in engineering who were really good students, and were good students in high school too. They were the A.P. students, and when they suddenly got Cs, they didn't know how to handle it. I mean, a hell of a lot of self-esteem is attached to those grades. So I think they go somewhere else to rebuild it. (Male white science non-switcher)

The students who left were smart enough. They were just extremely overwhelmed and scared to fail. (Female white female science non-switcher)

You get people that would probably do well if they were given half a chance, but there's so much competition, and not a heck of a lot of help. (Female black engineering senior)

It's the way this gentleman teaches. He believes in grading on a curve and slaughtering people in the first exam. You lose everyone 'cause no one's encouraging you to stay—the professor is very unapproachable. I think you lose a ton of good people. Why sit here and get slaughtered when they can go to another department and have some interaction with the professor, and some encouragement? (Male white science non-switcher)

Mostly, you have to be very willing to take the abuse to see yourself through it. The people who leave aren't necessarily any less talented, but they just say, 'Why do this?' (Male white engineering non-switcher)

I think they are losing a lot of intelligent people who would be very good engineers. One of my friends, he's...gonna switch into International Affairs. And my room-mate's a civil engineer with a 3.8 and just one year from graduation. But he's taking next year off: he just can't stand it any more. (Male white engineering non-switcher)

Weed-out classes also had the unintended effect of driving away some highly talented students because they lacked sufficient intellectual stimulation to sustain interest in the discipline:

The first two years in physics are so *dull.* I mean, they have absolutely nothing to do with what you'll be doing later. I'm afraid that's why you might be losing good students from engineering that are really qualified and have the intelligence...There are ways to make the introductory material interesting so that it doesn't drive away good people through boredom. (Male white engineering non-switcher)

Chemistry was something I excelled in and enjoyed. But there's no way of knowing when you get here that you are going to go on enjoying it. When I saw I was losing interest, I was surprised. But, looking back, it's really not that surprising. The first chemistry class was pretty uninspiring. Then I sat in for a few days on the next class, and I knew then it really didn't interest me any more. The idea of going on with that for four years was really unappealing. (Male white science switcher)

There's a great many who have been very good science and math thinkers their entire life, and who have high confidence. Then they get into engineering and find there's no more stimulation—it's just numbers and numbers and numbers. (Male Asian-American engineering switcher)

I don't think that many people who love science, math and engineering leave because they can't handle it, or because it's too hard...More often than not, people that I know have left because there hasn't been the intellectual fulfillment there for them. (Male white science switcher)

### *Differences Between Institutions in Student Concerns and Reasons for Switching*

Our most important finding with respect to institutional types is that we found very little difference between them in the nature and level of problems reported by current and former S.M.E. majors. Table 1.7 shows, for each campus, the five most commonly reported concerns contributing to switching. It also shows the five issues of greatest concern to students overall. Six factors contribute more than all other concerns to switching decisions across all seven institutions. At six of the seven institutions, switchers cited the same factor as the strongest contributor to switching decisions—namely, being drawn to a non-S.M.E. major which held more interest, or offered a better educational experience. This was closely followed by being "turned off science" by their experiences in S.M.E. classes. The only exception to this pattern was the public East Coast university where both switchers and non-switchers ranked poor teaching by S.M.E. faculty as their most serious concern. However, poor teaching was one of the top three concerns of non-switchers and students overall at all seven institutions, and it was highly ranked by switchers at most institutions. Though not as commonly cited as a reason for switching, at most institutions, both switchers and non-switchers placed poorly-founded initial choice of S.M.E. majors and the poor quality of advising, counseling and tutoring services high on their list of concerns.

Some concerns were more common on particular campuses, or groups of campuses. This is not because they indicate the unique 'flaws' of any institution. The same problems are likely to be found elsewhere among students with similar educational or socio-economic circumstances. It is not, for example, coincidental that the East Coast state university whose students were especially concerned about S.M.E. pedagogy was also the institution where we met the greatest confusion about the reliability of high school performance scores as an indicator of readiness for college-level S.M.E. work. More than at any other institution, students (who were largely drawn from the surrounding geographic area) had been encouraged to aspire to science and mathematics-based careers for which they were under-prepared. However, they could not have known the extent of their under-preparation without recourse to better objective teaching standards and measures of comparison. Retrospective concerns about the inadequacy of their high school preparation were also a major issue for non-switchers at highly selective institutions where more switchers and non-switchers cited the experience of conceptual difficulties than at institutions with less competitive entry. Questioning the adequacy of their high school preparation was also evident at institutions where the weed-out tradition was found to be strongest. Loss of confidence and discouragement engendered by low grades were highly ranked as a cause of switching in the two western state universities where traditional competitive assessment practices were strong—particularly in their Colleges of Engineering.

Accounts of financial difficulties in completing S.M.E. majors were almost always raised in conjunction with complaints about degrees which took more than four years to complete. The highest level of concerns about both issues were expressed at the two state universities where we also found the highest proportion of students working to pay for their own tuition, fees and living expenses, and spending the highest proportion of time in paid employment. The other institutions where one or both of these issues were highly ranked were the two most expensive of the private institutions. Concern that the career options and material rewards of an S.M.E. degree were unlikely to be worth the costs (in all senses) of completing it, were most marked wherever a high proportion of students expressed anxiety about the financial costs of their education.

It is also noteworthy that, in the small, private liberal arts college where we expected to find conditions more conducive to good educational experiences in science and mathematics, the main concerns of switchers and non-switchers differed little from those of students in other institutions. Although some aspects of the teaching emphasis traditional in liberal arts colleges were discernable, they were more in evidence in the non-sciences than the sciences, where aspects of weed-out traditions clearly lingered. In one regard, switchers at this institution reported more problems than did switchers in any other institution, namely, those related to curriculum pace and overload. This was a direct consequence of 'the block system' by which students study discrete areas of each discipline intensively for short periods of time. Although switchers found this a valuable way to learn in some disciplines, in science and mathematics they had insufficient time to gain a good conceptual grasp, think about the material, gain insights, or work confidently with abstract ideas too recently encountered. Finding enough time for laboratory work was a general problem in science classes in all institutions. It was even more difficult for students working within the block system, especially for those who were employed.

### *Differences Between Students Entering Engineering and those Entering Science or Mathematics*

Tables 1.8 and 1.9 summarize differences in the concerns of current and former majors in engineering from those in science and mathematics, and their significance for patterns of switching. Although engineering students described the same kinds of problems with their learning experiences as science and mathematics majors, engineering majors suffered from them more acutely. Half

TABLE 1.7 Comparative Ranking by Students at Seven Institutions of: Concerns Contributing to Switching; Concerns Raised by Switchers Overall; Concerns Raised by Non-Switchers; and Concerns of Students Overall.

**INSTITUTIONS: 1 = MWPUB1, 2 = WPUB2, 3 = WPUB3, 4 = ECPUB4, 5 = WCPRI1, 6 = WPRI2, 7 = WPRI3**

*MWPUB1 = Midwest, public, ranking 1; WPUB2 = West, public, ranking 2; WPUB3 = West, public, ranking 3; ECPUB4 = East Coast, public, ranking 4; WCPRI1 = West Coast, private, ranking 1; WPRI2 = West, private, ranking 2; WPRI2 = West, private, ranking 3; WPRI3 = Southwest, private, ranking 3; with ranking according to a modified version of the Carnegie Classification of Institutions (cf., Chronicle of Higher Education, July 8, 1987).*

| Issue | *Contributed to Switching Decision* | | | | | | | *All Switchers' Concerns* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Institution* | | | | | | | *Institution* | | | | | | |
| | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *1* | *2* | *3* | *4* | *5* | *6* | *7* |
| Non-S.M.E. major offers better education/more interest | 1 | 1 | 1 | 5 | 1 | 1 | 1 | | 3 | | | 2 | 1 | 1 |
| Lack of/loss of interest in S.M.E.: "turned off science" | 5 | 2 | 2 | 3 | 2 | 2 | 3 | | 4 | 4 | | | 2 | 2 |
| Rejection of S.M.E. careers/associated lifestyles | 3 | 3 | 3 | 4 | | | 2 | 5 | | 5 | 5 | | | 3 |
| Shift to more appealing non-S.M.E. career option | 2 | | | 2 | 3 | | 4 | | | | | | | |
| Poor teaching by S.M.E. faculty | | | 5 | 1 | | | | 1 | 5 | 2 | 1 | 1 | | |
| S.M.E. career options/rewards felt not worth effort to get degree | 4 | 5 | | | 4 | 3 | | | | | | | 5 | |
| Discouraged/lost confidence due to low grades in early years | | 4 | 4 | | | | | | | | | | | |
| Prefer teaching approach in non-S.M.E. courses | | | | | 5 | 4 | | | | | | | | |

TABLE 1.7 (continued) Comparative Ranking by Students at Seven Institutions of: Concerns Contributing to Switching; Concerns Raised by Switchers Overall; Concerns Raised by Non-Switchers; and Concerns of Students Overall.

**INSTITUTIONS: 1 = MWPUB1, 2 = WPUB2, 3 = WPUB3, 4 = ECPUB4, 5 = WCPRI1, 6 = WPRI2, 7 = WPRI3**

| *Issue* | *Non-Switchers' Concerns* | | | | | | | *All Students' Concerns* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Institution* | | | | | | | *Institution* | | | | | | |
| | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *1* | *2* | *3* | *4* | *5* | *6* | *7* |
| Non-S.M.E. major offers better education/more interest | | | | | 3 | | | | 4 | 5 | 5 | 2 | 2 | 2 |
| Lack of/loss of interest in S.M.E.: "turned off science" | | | | | 5 | | 3 | | 5 | | | 5 | | |
| Rejection of S.M.E. careers/associated lifestyles | | | | | | | | 5 | | | | | | 5 |
| Shift to more appealing non-S.M.E. career option | | | | | | | | | | | | | | |
| Poor teaching by S.M.E. faculty | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 3 | 1 |
| S.M.E. career options/rewards felt not worth effort to get degree | | | | 5 | | | | 4 | | | | | | |
| Discouraged/lost confidence due to low grades in early years | | | | | | | | | | | | | | |
| Prefer teaching approach in non-S.M.E. courses | | | | | | | | | | | | | | |

TABLE 1.7 (continued) Comparative Ranking by Students at Seven Institutions of: Concerns Contributing to Switching; Concerns Raised by Switchers Overall; Concerns Raised by Non-Switchers; and Concerns of Students Overall.

INSTITUTIONS: 1 = MWPUB1, 2 = WPUB2, 3 = WPUB3, 4 = ECPUB4, 5 = WCPRI1, 6 = WPRI2, 7 = WPRI3

| *Issue* | *Contributed to Switching Decisions* | | | | | | | *All Switchers' Concerns* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Institution* | | | | | | | *Institution* | | | | | | |
| | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *1* | *2* | *3* | *4* | *5* | *6* | *7* |
| Curriculum overload, fast pace overwhelming | | | | | | | 5 | | | | | | | 4 |
| Conceptual difficulties with one or more S.M.E. subject(s) | | | | | | 5 | | | | | | | 4 | |
| Reasons for choice of S.M.E. major prove inappropriate | | | | | | | | 3 | 1 | 1 | 2 | 3 | 3 | 5 |
| Inadequate advising or help with academic problems | | | | | | | | 2 | 2 | 3 | 3 | 4 | | |
| Inadequate high school preparation in basic subjects/ study skills | | | | | | | | | | | 4 | 5 | | |
| Financial problems of completing S.M.E. majors | | | | | | | | 4 | | | | | | |
| Unexpected length of S.M.E. degree: more than four years | | | | | | | | | | | | | | |
| Language difficulties with foreign faculty or T.A.s | | | | | | | | | | | | | | |

TABLE 1.7 (continued) Comparative Ranking by Students at Seven Institutions of: Concerns Contributing to Switching; Concerns Raised by Switchers Overall; Concerns Raised by Non-Switchers; and Concerns of Students Overall.

**INSTITUTIONS: 1 = MWPUB1, 2 = WPUB2, 3 = WPUB3, 4 = ECPUB4, 5 = WCPRI1, 6 = WPRI2, 7 = WPRI3**

| *Issue* | *Non-Switchers' Concerns* | | | | | | | *All Students' Concerns* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Institution* | | | | | | | *Institution* | | | | | | |
| | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *1* | *2* | *3* | *4* | *5* | *6* | *7* |
| Curriculum overload, fast pace overwhelming | | | | | | 4 | | | | | | | | |
| Conceptual difficulties with one or more S.M.E. subject(s) | 5 | 5 | | | 4 | | 2 | | | | | | | |
| Reasons for choice of S.M.E. major prove inappropriate | 3 | 4 | 2 | 3 | | | 4 | 2 | 2 | 1 | 2 | 3 | 5 | 4 |
| Inadequate advising or help with academic problems | | 2 | 3 | 4 | | 3 | | 3 | 3 | 3 | 3 | 4 | 4 | |
| Inadequate high school preparation in basic subjects/ study skills | | 3 | 5 | 2 | | 1 | | | | 4 | 4 | | 1 | |
| Financial problems of completing S.M.E. majors | 2 | | | | 2 | | | | | | | | | |
| Unexpected length of S.M.E. degree: more than four years | 4 | | 4 | | | | 5 | | | | | | | |
| Language difficulties with foreign faculty or T.A.s | | | | | | 5 | | | | | | | | |

TABLE 1.8 "The Problem Iceberg: Engineering Majors." Factors Contributing to Switching Decisions of Former Engineering Majors, All Concerns of Engineering Switchers, of Non-Switchers and of All Students.

| *Issue* | *Factor in switching decisions (%)* | *All switchers' concerns (%)* | *All non-switchers' concerns (%)* | *All students' concerns (%)* |
|---|---|---|---|---|
| Lack of/loss of interest in SME: "turned off science" | 50 | 66 | 41 | 49 |
| Curriculum overload, fast pace overwhelming | 45 | 55 | 52 | 54 |
| Poor teaching by SME faculty | 41 | 98 | 86 | 93 |
| Non-S.M.E. major offerrs better education/more interest | 37 | 57 | 35 | 48 |
| S.M.E. career options/rewards felt not worth effort to get degree | 31 | 43 | 18 | 32 |
| Shift to more appealing non-S.M.E.career option | 30 | 36 | 14* | 27 |
| Inadequate advising or help with academic problems | 26 | 81 | 53 | 69 |
| Discouraged/lost confidence due to low grades in early years | 25 | 40 | 14 | 29 |
| Rejection of S.M.E. careers and associated lifestyles | 24 | 44 | 29 | 38 |
| Reasons for choice of SME major prove inappropriate | 20 | 94 | 52 | 76 |
| Financial problems of completing S.M.E. majors | 18 | 32 | 29 | 31 |
| Morale undermined by competitive SME culture | 16 | 30 | 9 | 21 |
| Conceptual difficulties with one or more S.M.E. subject(s) | 15 | 32 | 29 | 31 |
| Lack of peer study group support | 14 | 19 | 12 | 16 |
| Inadequate high school preparation in subjects/study skills | 10 | 38 | 37 | 37 |
| Unexpected length of S.M.E. degree: more than four years | 10 | 29 | 38 | 32 |
| Discovery of aptitude for non-S.M.E. subject | 10 | 11 | 3 | 8 |
| Prefer teaching approach in non-S.M.E. courses | 6 | 24 | 4 | 18 |
| Language difficulties with foreign faculty or T.A.s | 4 | 34 | 18 | 27 |
| Switching as means to career goal: system playing | 4 | 6 | 0 | 3 |
| Poor teaching, lab, or recitation support by T.A.s | 0 | 22 | 14 | 18 |
| Problems related to class size | 0 | 20 | 14 | 17 |
| Poor lab/computer lab facilities | 0 | 3 | 6 | 4 |

*Issue raised by non-switchers intending to move into non-S.M.E. field following graduation.

TABLE 1.9 "The Problem Iceberg: Science and Mathematics Majors." Factors Contributing to Switching Decisions of Former Science and Mathematics Majors, All Concerns of Science and Mathematics Switchers, of Non-Switchers and of All Students.

| *Issue* | *Factor in switching decisions (%)* | *All switchers' concerns (%)* | *All non-switchers' concerns (%)* | *All students' concerns (%)* |
|---|---|---|---|---|
| Non-S.M.E. major offers better education/more interest. | 44 | 60 | 29 | 45 |
| S.M.E. career options/rewards felt not worth effort to get degree | 40 | 52 | 22 | 38 |
| Lack of/loss of interest in S.M.E.: "turned off science" | 37 | 53 | 31 | 43 |
| Rejection of S.M.E. careers and associated lifestyles | 34 | 42 | 15 | 29 |
| Curriculum overload, fast pace overwhelming | 25 | 36 | 34 | 35 |
| Poor teaching by S.M.E. faculty | 32 | 83 | 64 | 74 |
| Shift to more appealing non-S.M.E. career option | 30 | 29 | 19* | 24 |
| Inadequate advising or help with academic problems | 22 | 70 | 51 | 61 |
| Discouraged/lost confidence due to low grades in early years | 21 | 28 | 12 | 20 |
| Inadequate high school preparation in subjects/study skills | 20 | 44 | 38 | 41 |
| Financial problems of completing S.M.E. majors | 16 | 27 | 19 | 23 |
| Morale undermined by competitive S.M.E. culture | 13 | 27 | 9 | 18 |
| Prefer teaching approach in non-S.M.E. courses | 12 | 24 | 20 | 22 |
| Unexpected length of S.M.E. degree: more than four years | 8 | 12 | 20 | 16 |
| Conceptual difficulties with one or more S.M.E. subject(s) | 10 | 22 | 22 | 22 |
| Discovery of aptitude for non-S.M.E. subject | 10 | 12 | 6 | 9 |
| Switching as means to career goal: system playing | 10 | 12 | 5 | 8 |
| Reasons for choice of S.M.E. major prove inappropriate | 9 | 71 | 30 | 51 |
| Lack of peer study group support | 9 | 15 | 4 | 10 |
| Language difficulties with foreign faculty or T.A.s | 2 | 25 | 22 | 24 |
| Problems related to class size | 0 | 20 | 9 | 15 |
| Poor teaching, lab, or recitation support by T.A.s | 0 | 17 | 18 | 13 |
| Poor lab/computer lab facilities | 0 | 5 | 2 | 4 |

*Issue raised by non-switchers intending to move into non-S.M.E. field following graduation.

of engineering switchers (49.5%) cited loss of interest in the major, almost half (45.1%) cited curriculum overload and over-fast pace, and 40.7 percent cited poor teaching, as having directly contributed to their decision to leave. The comparative percentages for science and mathematics switchers are much lower (i.e., 37.0%, 25.0% and 31.5% respectively) and no other teaching and learning issue is as highly rated by science and mathematics switchers as it is by engineering switchers. Despite greater selectivity in the admission of engineering freshmen, more engineering switchers (15.4%) than science and mathematics switchers (8.7%) cited conceptual difficulties as contributing to switching decisions. This again points to the higher level of difficulty that engineering students experienced with the pedagogy, curriculum pace and assessment practices of their majors. Although the pedagogy in some science departments encouraged strong competition for grades, current and former engineering majors unanimously reported their classes to be highly competitive. As a consequence, failure to develop collaborative and supportive study groups contributed to the switching decisions of more engineers than non-engineers, and was a generalized problem among all engineering students.

The concerns leading to switching among former science and mathematics majors focused more on disappointments and anxieties about career prospects than those of engineers. Science and mathematics switchers more commonly left their majors because neither the career options and material rewards, nor the personal satisfactions of careers open to them, appeared sufficient to justify the effort involved in graduating. (The comparisons for these two issues are 40.2 percent and 33.7 percent for science and mathematics switchers, and 30.8 percent and 24.2 percent for engineering switchers.) This was not because students in science and mathematics majors were more materialistic than engineering majors. Indeed, the contrary is true. More engineering (19.8%) than science and mathematics switchers (8.7%) cited inappropriate choice as contributing to their switching decision, and the ill-founded choices of engineering switchers more commonly included a predominantly materialist motivation, insufficiently supported by interest, than did the choices of other switchers. Engineering students entered their major expecting more in material terms from their future careers than did science and mathematics freshmen (though they did not necessarily know more about the nature of the jobs they might undertake). The discomforts of the weed-out system, including the competitive ethos, were also greater in engineering (and other classes and majors preparatory to professional qualifications, especially pre-medicine). Engineers were, however, more prepared to tolerate these discomforts than other S.M.E. majors, so long as they saw themselves as likely to have good salaries and career prospects following graduation. They were also more likely to see the process of gaining a degree in 'commodity' or 'investment' terms—that is, as a calculated risk in expenditure of time, effort and money to gain a profitable outcome. Engineering students overall expressed more anger than non-engineers that their degrees took longer and cost more than their advertised length of four years. Science and mathematics majors were also dismayed when degrees took longer than they had expected, but did not share the feelings of betrayal which engineers expressed towards their colleges. Engineering seniors also expressed more financial concerns (28.8%) than science and mathematics seniors (18.6%), but it is not clear from the text data that they actually experienced more financial difficulty than other students in completing lengthy degrees.

Although science and mathematics majors were less materialist in their first or subsequent choices than engineers, they expressed much more anxiety about the availability of jobs. As freshmen, they were also less clear than students entering engineering about the career path they wished to follow, had less knowledge about the careers open to them, and were more fearful about the prospects of getting any job. Mathematics majors were the least certain about the careers open to them, or what they would do after graduation. Science and mathematics majors were more likely than engineers to consider graduate degrees, both as a traditional career path in their disciplines and (increasingly over time) as a way to cope with deteriorating employment prospects for science and mathematics baccalaureates. They were also less willing than engineers to tolerate teaching practices that reflected the weed-out system because they had less to gain, in career terms, by doing so. With the exception of students intending to enter the medical professions, science and mathematics majors were less instrumental than engineering students in their reasons for choosing S.M.E. majors, and in their evaluations of the quality of their undergraduate education. Both switchers and non-switchers in science and mathematics were more likely than engineering students to criticize faculty for failing to provide a satisfying educational experience, and to consider alternative majors for educational reasons. With the exception of 'pre-med' majors, who show a pattern of strategic switching to improve their chances of getting into medical schools of their choice, science and mathematics switchers left for reasons which reflect a concern to find work that is satisfying in nature, context, or purpose.

In the chapters which follow, we discuss each of the issues which contribute to 'the problem iceberg' broadly in the order in which students encounter them. We also group together problems which students see as interrelated. The ordering of the chapters does not, therefore, follow the rank order of problems in terms of their contribution to switching decisions. We also present the insights we have gained about S.M.E. students' concerns, including those which contribute to switching, using their own words. Issues are summarized between sections of quotations, but there is much to be learned by hearing the authentic voice of the students themselves.

## Notes

1. The American Freshman studies are conducted by the American Cou Education and U.C.L.A.'s Cooperative Institutional Research Program at the Education Research Institute.

2. S.M.E. majors vary in the proportion of 'top' students each group attracts: b 1978 and 1988, engineering drew an increased share of A and A- students (from to 17.4%); the share of life sciences remained steady at 7.9%; that of the p sciences and pre-medicine majors dropped (by 18.2% and 10.5%, respectively); share of the social sciences rose slightly (8.8% to 9.8%).

3. Their estimates exclude graduates for whom a terminal baccalaureate is ap ate—as in engineering.

4. Retention among black, Hispanic, and native American students in S.M.E. has remained low, despite improved enrollments (cf., Collea, 1990; O.S.E.P., N.S.F., 1988, 1989a, 1990b, 1994; O.T.A., 1989). Women's enrollment sh twenty-year decline, despite enhanced recruitment efforts; and the retention rate o ability entering women remains poor (cf., O.S.E.P., 1987b; Vetter, 1988; N.S.F., 1989a, 1990b, Green, 1989a, 1989b).

5. A discussion of their findings on the causes of attrition is included in the N Report, "The State of Academic Science and Engineering" (1990a).

6. This follows the precedent set in some earlier studies, most notably: O.T.A., Lee, 1988; Tobias, 1990; and the series of American Freshman survey reports Higher Education Research Institute, U.C.L.A. In institutions where undergraduat not required to declare a major until sophomore year or later, we initially estimate student's incoming intention to declare an S.M.E. major by their concentration of c in mathematics and science taken as freshmen and sophomores. Confirmation th had been their intention was sought from each potential participant in a short tele interview before inviting them to take part in the study.

7. Figure A.1, *Appendix A*, indicates the disciplines included in each group of n in the C.I.R.P. data.

8. These persistence rates closely match those found for men (66%) and for w (48%) by Strenta et al. (1993).

9. In the health professions the pattern is less distinct because this group inc majors which lie at both extremes of traditional male and female professional prec nance, namely, pre-medicine and pre-dentistry on the one hand, and nursing an therapeutic professions on the other.

10. The reason for this is that, as one approaches the end of data collection in an ethnographic study, though there is always the possibility that new information will emerge from those who have experienced the problems being discussed, those who have survived them increasingly act as a source of validation rather than of new information.

11. In *Appendix A*, Figure A.2 shows the number and percent of switchers and non-switchers in our sample who were in engineering, and in science or mathematics.

12. In *Appendix A*, Figure A.3 shows the profile of switchers and non-switchers at each institution by discipline, sex and race/ethnicity. Figure A.4 shows the profile of non-white switchers and non-switchers by discipline and racial/ethnic group.

13. The topical outline produced by this process is included in *Appendix B*.

14. The study was undertaken in two phases, beginning with four institutions of different type in our own state.

15. Cf., Carnegie Foundation. 1987. Carnegie foundation's classifications of more than 3,300 institutions of higher education. *Chronicle of Higher Education, 33*: 22.

16. For evaluation of programs at women's colleges, see: Blum, L., & Givant S., 1982, "Increasing the Participation of College Women in Mathematics-Related Fields," in *Women and Minorities in Science: Strategies for Increasing Participation*, S.M. Humphreys, ed., Boulder, CO: Westview Press; Mappen, E.F., 1990, "The Douglass Project for Rutgers Women in Math, Science, and Engineering: A Comprehensive Program to Encourage Women's Persistence in these Fields," in *Women in Engineering Conference: A National Initiative* (conference proceedings), J.Z. Daniels, ed., West Lafayette, IN: Purdue University; Rayman, P., 1992, "Opportunities for Women in Science: The Undergraduate Experience." Paper presented at the National Research Council conference, Irvine, CA, Nov.4-5. Published proceedings: *Science and Engineering Program: On Target for Women?* 1992. Washington, D.C.

17. Seidel, John V., Kjolseth, J. Rolf, & Elaine Seymour. 1988. *The Ethnograph: A User's Guide*. Littleton, CO: Qualis Research Associates.

18. Tables 5.1 and 5.2, which compare the concerns of male and female switchers and non-switchers, are presented and discussed in Chapter 5.

19. All figures in the "iceberg" tables are rounded to the nearest whole number: those in the text are given to one decimal point.

20. Humphreys, Sheila M., & Robert Freeland. 1992. *Retention in Engineering: A Study of Freshman Cohorts*. Berkeley, CA: University of California at Berkeley, College of Engineering.

21. McClelland, L. 1993. *Students Entering Science, Mathematics, and Engineering Majors as Fall Freshmen, 1980-1988*. Unpublished data provided by the University of Colorado, Boulder, Office of Research and Information.

22. These observations are consistent with those of Sheila Tobias in her 1990 report, *They're Not Dumb, They're Different*, and in a number of articles arising from her work.