INTRODUCTION

Young girls do not start out with **low** achievement in science. (In this hook, the term "science" is often used to refer to the areas of science, math, and engineering.) Early in thr high school pears. however, many girls experence the beginning of a departure from science typified by enrollment in fewer science courses, lowered achievement ard increasingly negative attitudes. The significant loss of talented young women from science education and occupations is the focus of this book.

Even though women have been entering the formal workplace in record numbers since the middle ofthe mentieth century; they have not entered jobs in science **at** a similar rate. Women represent 46 percent of the U.S. labor force. but they hold only 22 percent of the jobs in math, science, and engineering (National Science Foundation. 1994). Somewhere along the way, between the earliest training and entry into the labor markrt. gender stratification occurs. Science jobs are among the highest paying, highest status jobs in the labor market The shortage of women in this area helps maintain gender inequalities and represents a significant amount of lost talent

Recent Reports on Gender and Science

There is considerable agreement among researchers educator:, and policy makers that the last few decades have seen progress for women in science. Young women are now as likely as young men to take certain high school math and science courses. The gender gap in average math proficiency scores has disappeared at ages 9 and 13 and has nearly disappeared at age 17. Tne numbc- of women earning advanced degrees in math and science is increasing, as **is** the number employed in math and science occupations (National Science Foundation, 1993, 1994; National Science Board, 1993; American Association of University Women [AAUW], 1992; National Center for Education Statistics, 1994). In spite of these gains, however, the gender gap in science has not disappeared. Recent rsports rising infvrmation on students and workers in the 1990s provide alarming evidence of the persistance of the gender gap in science:

- In elementary school, young girls are less confident of their abilities in science and math and less interested in careers in science and engineering than are young boys. This is true in spite of similar exposure to courses and similar achievement (National Science Foundation, 19941.
- Surveys of 17-year-olds show that young women take fewer advanced courses in math and are less likely to take chemistry and physics courses than are young men (AAUW, 1992; National Science Foundation, 1993, 1994; National Science Board, 1993; National Center for Education Statistics. 1994).
- Surveys of 17-year-olds also show that gender difference: persist in math proficiency scores at the highest levels (e.g., algebra and multistep problem solving) and in math achievement test scores. Beginring at age 9, there are gender differences favoring **males** in both science proficiency (what the student knows and can do) and science achievement (what the student should know and should be able to do) test scores (National Center for Education Statistics, *1994,* National Science Board, 1993).
- In their last year of high school, young men are more than three times as likely as young women to expect to pursue a career in science, math, or engineering (National Science Foundation. 19941.
- In many areas of science at the secondary and postsecondary level, teachers are overwhelmingly male. Teachers at all levels of edusation and of hoth sexes discriminate in the classroom and have lower expectations in science and math for females than for males (AAUW, 1992; National Science Foundation, 1994).
- Parents also discriminate against daughters. **A** majority of parents believe that their sons are better in mechanics and math than their daughters, and they fail to give their daughters the most elementary :raining in the use of tools **to** build or repair mechanical objects (Vetter, 1992).
- Although women have earned the majority of bachelor's degrees in all fields combined since 1982, :hey earn a smaller portion of bachelor's degrees in science and engineering (44%) Women are especially underrepresented in engineering, where they earn only 15 percent of the undergraduate degrees. Although thr proportion of master's degrees and doctorates earned by women in science and engineering has increased. women are still underrepresented here as well. They receive **45** percent of **the** master's degrees in science and engineering fields and 29 percent of the doctorates. In engineering, women account for only 14 percent of the master's degrees and 9 percent **of** the doctoral degrees. At all post-

secondary levels, women are more likely to drop out of science and engineering programs than are men. A vast majority of women in science programs are in life sciences, psychology, and social sciences. Recent evidence suggests that the 20-year trend toward less sex segregation in fields of study has slowed down considerably (National Science Foundation. 1994; Hollenshead, Wenzel Lazarus, & Nair, in press: Fox, 1995; Jacobs, 1995).

■ Women make up *42* percent of the labor force but only 22 percent of the science and engineering labor force Within this labor force, they hold lower status positions, receive smaller salaries, and are more likely to be unemployed or underemployed compared to their male counterparts. Many of these differences persist when qualifications are taken into account. Despite initiatives on the part of industry to recruit and retain women, women scientists are less likely than men scientists to be employed in the industrial sector of the market (Rosser, *1990;* Rayman & Brett, **1993;** National Science Foundation. 1994; Fox, 1995, in press: Long, Allison. & McGinnis, 1993; Zuckerman, 1991).

■ Institutional practises that begin in graduate school and continue in the workplace function to keep women out of science. In a recent survey of engineers, 56 percent of the women said that they were aware of cases where females had been overlooked with regard to career opportunities. Another survey of women scientists showed that large numbers had experienced or witnessed sex discrimination or harassment. There is considerable evidence that the culture of science in the workplace continues to be a male culture (Rosser. 1990, Vetter. 1992: Fox. 1995. in **press;** Alper, 1993: Zuckerman, 1991; Devine, 1992, Rayman and Brett. 1994).

The Science Pipeline and Limitations of Past Research

Many researchers and policymakers use the imagery of a science pipeline to think about the relative access of women and men to the fields of science, math, and engineering. The image is one of a training pipeline running from early training in primary and secondary school through advanced training in the university to the hiring of **qualified** scientists in the labor market.

Berryman (1983) was one of the first to introduce the notion of the science pipeline and the formation of a scientific talent pool from which science professionals could be drawn. Aptitude, course taking, and achievement are often used to determine whether a student is in or out of the pipeline. When visualizing the pipeline, it is perhaps more accurate to think of it as a funnel, since all elementary school students are in the pipeline but many drop out along the way. Research on women's participation in this pipeline shows a pattern of declining course taking and achievement along with increasingly negative attitudes about science. Most researchers have supgested that this decine begins in high school and worsens in the undergraduate and graduate years (Office of Technology Assessmnt, 1988; Oakes, 1990; National Science Board, 1993; AAUW, 1992; National Science Foundation, 1953, *1994;* Rayman & Brett, 1993; Brush, 1991; Barber, 1995). Sells (1978; 1980) considers advanced high school math classes the "critical filter" that keeps many women from entering the male-dominated math and science prnfessions.

Although the pipeline imagery is becoming pervasive in tne literature, and descriptive information on the number and characteristics of men and women in math courses or with high math scores is available, the researchin this area has a number of limitations. These limitations go beyond the well-known problems of unrepresentative samples and inconsistent measures that have led to conflicting findings (Oakes, 1990). There is surprisingly little research that provides insight into the complexities of the process by which *so* many women opt out of science.

A good example ofthe lack of attention to these complexities in past research is the tendency of many analysts to focus on single dimensions of the science experience or single dimensions of factors affecting science experiences. For example, Oakes (1990) has noted that much attention has been giver to women's math experiences, but that very little attention has been aimed at their ***science*** experiences. In a similar fashion, researchers often focus on a particular dimension of experience, such as achievement, course taking, or attitudes. The implicit assumption has been that the different areas of experiencr are related in such a way that knowledge of the experience in one area reveals insights into the experience in other areas. There is, however, evidence that the different dimensions of experience in math and science arc not so perfectly correlated (Oakes, 1990).In fact, young girls' attitudes about math and science may turn from the positive long before they stop taking the classes (Mullis &Jenkins, 1988). And even after many girls stop taking the math and science classes, those who stay in the dasses **do** not get lower grades than their male counterparts, although their standardized scores are usually lower (DeBoer, 1984a; Linn & Hyde. 1989).

In my research, I explore four aspects of experience in both math **and** science achievement (e.g., grades and standardized test scores), acccss (e.g., course taking), attitudes, and activitirs (e.g., use of calculators, microscopes, computers and the like). The first three of these tavc been given some attention in the literature, but **we** know less abcut young women's *activities* in math and science. Researchers and the federal agencies that monitor science achievement in the United States have suggested that these areas of science are important dimensions of students' science experience (National Science Foundation. 1993; National Science Board, 1993; National Center for Education Statistics. 1994; Oakes, 1990; Morgan, 1992; Smith, 1932; Catsambis, 1994). Importantly, I consider all four of these dimensions and their interrelationships in trying to understand women's experiences in the sciences.

In genera!, we **know** much *more about women's* experiences than we know about the causes of these experiences. When researchers do look at causes, they often follow the same unidimensional approach that they use to describe science experiences. Some researchers have focused on schools and teachers, some on personality characteristics and choices, and some on family characteristics. Although these studies **are** important, the) do not provide a view of the entire process leading to success in science or of the complexities in that **process.** For example, when researchers focus on personality characteristics (e.g., Meece, Wigfield, & Eccles, 1990), explanations for the original source of the personality differences are often not attended to.

In my study of women in science, I consider four sets of causal factors gender, family resources, school resources, and individual resources. I describe women's science experiences **as** being at the end of a complex path of causal influences. That is, the influence of gender is not necessarily just a direct influence, hut rather it might also work indirectly through family experiences that affect school experiences and that ultimately affect individual characteristics and experierces.

Additionaly, researchers have been slow to realize the ways in which the individual and social factors that are typically seen as causes of science experiences night interact with each other to affect those experiences. Likewise, these individual and social factors might nteract with cxperienses in one area of science (e.g., attitudes) to in **turn** affect experiences in another area of science (e.g., achievement) (Oakes, 1990). This research acknowledges the fact that women's resources in one area of life might interact in a unique way with resources in other areas by carefully examining interactions between multiple **causes** of science experiences. A set of interactions that are particularly important for understanding the complexities of women's science experiences are those involving gender. race, acd social class. Special attention **is** thus given to these interactions in this research.

Although some researchers have used multidimensional models to examine women's science cxperienccs (Wise, 1985; Ethington & Wolfe, 1986; Ware **&Lee,** 1988 Marsh, 1989), these experiences havr typically been addressed in **a** relatively static way (see Rayman & Brett, 1993; Wise, 1985; Lee, 1987; and Marsh, 1989 for studies that are an exception to this static approach). Some researchers use cross-sectional data to infer causal relationships (e.g., Boli, Ramirez & Meyer, 1985). Even when longitudinal data are used, science experiences are often seen as a one-time outcome, with early science experiences included as independent variables predicting later experiences. Some researchers use longitudinal data to present "snapshots" of students' experiences in the different time periods. In effect, they are using longitudinal data in nearly a cross-sectional fashion. This is especially problematic given evidence that the science pipeline is very fluid, with many students entering and exiting (Berryman. 1983, Office of Technology Assessment, 1988). It cannot be assumed that snapshots of students at various points in time (even snapshots using longitudinal data) represent the same pool of students. In addition, longitudinal studies examining the pipeline from high school into careers are rare. A long-term approach, which does not stop with the end of education, is important given the evidence showing a considerable exiting from the sciences after college and graduate school and before young people enter occupations (Berryman, 1983; Natinnal Science Board, 1993). In this research, the fluidity and long-term nature of experiences are recognized by following young people and developing patterns of experiences over time—science trajectories. These trajectories begin with early training in high school and extend to postsecondary school and occupations. For example, some individuals will hrvc early success and interesr in science but will drop out at critical decision points (e.g., after their sophomore year in high school, after their senior year, after college) while others will drop out later or stay in the pipeline. In other words. this research describes distinct patterns or trajectories that women experience in science and the school. family, and personal/psychological experiences as well as resource; that are associated with the trajectories. Few researchers have looked P multiple sets of experiences in the sciences over time as outcomes to be predicted. The research reported here follows the life course perspective in acknowledgin: the fact that science experiences, like other individual experiences, are not one-time events hut rather are dynamic and constantly ctanging, with much variatinn between individuals in thr way they are encountered (George, 1993).

Another limitation of the literature on women in science is its atheoretical nature. The typical approach to the problem is to create a long lis: of independent variables and test them for statistical significance. The emphasis is on statistical sophistication. no: on theoretical development. Thus when statistical relationships are found, there is no broader conceptual context within which the findings can be interpreted and understood. In the research presented here, a conceptual framework involving the creation of lost talent through selection processes and unequal resources is used to look at the role gender plays. Both differential treatment on the basis of gender and cifferences in family, school. and individual resources are seen as critical factorr in understanding why so many talented women leave the sciences.

Another c-itical shortcoming of much of the research on gender differences in science is the tendency to make conclusions ahout "hoys" and "girls" without paying attention to important statuses other than gender, mainly race and **class. We** know that low-SES (socioeconomic status) and non-Asian minority youth have lower achievement in science than do their **upper-SES** white counterparts (Oakes. 1990; National Scirnce Foundation, 19941, But some have found that African American youth hold more positive attitudes about science than any other subgroup (Hueftle et al., 19831. Thus *we* cannot assume that some or all of the science experiences of African American women will be more negative than those of white women. Interestingly, some have found .African American girls to be more positive ahout math and science than their white counterparts (Dossey, Mullis, Lindquist, & Chambers, 1988). Can we conclude that the gender pattern among white youth is duplicated amongst nonwhite youth? The limited research which is available suggests that we cannot. For example, athough overall gender contrasts show hoys in more advanced high school math courses than girls, among African American youth, the opposite pattern prevails (Mattews, 1984).

A final limitation of past research on women in science involves the emphasis on tie individual actions and decisions of women in the science education realm as separate from larger structural processes involving education and occupation systems. That is, the link between the reproduction of power and status at the macro level and the individual expectations and attitudes of young men and women is seldom acknowledged. Work hy Kerckhoff (19761, Bourdieu (1973). and others that shows how culture is reproduced and how personal education and occupational choices draw on real structures and opportunities **is** essential for understanding the loss of talented young women from science. Fox's (1995, in press) work on women in science occupations provides further support for the importance of structural factors over individual factors in understanding women's success in science When different school, Family, and individual experiences of young women **are** examined in this research, they are viewed as reflections of gender differences in power at the macro lwei.

Recent work showing how advances for women in science training have not been equally matched **by** their increased envance into scientific occupations sheds more ligh: on the need for a structural approach to women in thr sciences (Stockard, 1985; Charles, 1992). In spite of these findings, the majority of work on women's access to science professions assumes that training is tie key to occupational equality and focuses solely on the factors that would enhance that training (e.g., teachers, curriculum, nonbiased boks, etc.) (Ware & Ler, 1988; Fennema & Peterson, 1985; Eccles & Jacobs, 1986; *Hess* & Ferree. 1987; Fox, Brody, & Tobins, 1985).

These limitations **leave** many unanswered questions about women's experiences in science Do young women lose interest in science at the same rate as they lose interest in math? Is this true for all women, regardless ***of*** their social class and race? Do they experirnce a decline in all aspects of math and science, including achievement, course taking, attitudes, and activities? Does gender have **a** direct intluence on science experiences, such that equally qualified girls and boys end up with difFercnt experiences, *o:* docs it indirectly affect science experiences through the unique family, school. and individual characteristics of women? What are the characteristics of women who stay in science? Are their families different: their schools? Are these characteristics causes of perseverance or just correlates? *In* sum, although the alarm has been rung on the shortage of women in science; we have not come very lar in our understanding of the cornplexitiei of women's experiences in science nor of the complexities of the explanations for these experiences.

In this research, groups of young women are followed over time in an attempt to begin to understand these complexities. Using large, national samples of young people and **a** conceptual framework that suggests that deficits in resources ars a key in understanding the loss of scientifically talented young women from **the** sciences, the research **seeks** to discover the complicated patterns of women's experiences in diverse areas of science. It also presents a picture of **the** successful woman scientist—what her family is like, what her school provided her, and what personal strengths she had that made the difference m beating :he odds. Before describing these women and their experiences, it is important to consider the larger social and economic context of stiencc in the United States.

The State of Science and the Economy in the United States

We are living in a society that **is** increasingly reliant on science and technology. With the Soviet launchirg of Sputnik in 1957, a push to produce more and better U.S. physicists, chemists, mathematicians, engineers, and medical researchers began. Since then, the United States has been an international leader in research and technology Rut whether the United

States can retain that lead is far from certain. Voted scientist Carl Sagan (1989) has concluded that we "live ir a society dependent on science and technology in which hardy anyone knows anything about science and technology" Changes in the economy have not resulted in larger numhers of students going into science and engineering. The percent of college students majoring in science and engineer ng has remained constant over the past 30-some years (Vetter, 1987; National Science Board, 1993). Others suggest that interest in these fields may actually he waning. In 1988 less than 1 percent d college freshmen said that they would major in mathematics. down from 4 percent two decades ago. Physics and chemistry majors fell from 3 percent to 1.5 percent. (Tift, 1989). The late 1980s saw a similar decline in interest in engineering, although in 1990 and 1991 enrollment in engineering programs increased slightly after a 9-year decline (National Science Board, 1993).

International comparisons of students provide additional cause for concern. Thr best American students are not competitive with their peers in other countries when it comes to math and science. The Second International Math Study (SIMS) and the Second International Science Study (SISS) look at students from 20 countries, including the United States. They show that students from many other countries, including Japan, Hong Kong, England and Wales, and Sweden, know much more math and science than do even the best students in the United States. One of the findings from the science study is that U.S. studrnts were tied in science with students in Singapore and Thailand for fourteenth place in a group of 20 countries (International Association for Evaluation of Educational Achievement, 1988; McKnight et al., 1985).

Concern about U.S. competitiveness in sciencr and technology is rampant. It is fueled not only by the state of science education in the United States but by the consequences of weakening competitiveness for America's economy, standard of living. and national security. It is in the nation's interest to have high-quality education in science and engineering. Well-educated workers are increasingly seen as the "human resources" or "human capital" that is required for a competitive advantage (Office of Technology Assessment. 1988; National Commission on Excellence in Education. 1983). The state of science education is not the only problem looming in the country's science future, however. Demographics add a further complication.

Demographers (Wetzel, 1988), labor economists (Leontief & Duchin, 1986), and concerned government and business leaders (Brock, 1986; Perot, 1988) recognize a potential problem in the nation's labor pool. Projected retirements in the science and engineering sector during the 1990s will reduce this segment of the work force by about half (Finkbeiner, 1987). According to ths National Science Fcundation, 60 to 70 percent of current faculty members in engineering and natural sciences will be retiring or leaving their positions in the next two decades (Teltsch, 1991). Regardless of whether the number of exiting scientists is as large as this, the documented stable or declining interest in science and engineering majors in recent decades does not suggest a labor pool rising to fill these openings.

Future work cohorts will include increasing numbers from two groups—women and racial minorities (Oakes, 1990). Most of the college freshmen of 2005 were born by 1987. Demographers tell us that because of the **low** birth rates of the 1960s and 1970s and the resultant "baby bust" generation, the number of 18-year-olds is declining and will not stop doing so until the mid-1990s (Office of Technology Assessment, 1988). At the same tine the number of women getting college degrees and the number of minority youth are increasing. Women and non-Asian minorities have not historically held degrees or jobs in mathematics, science, or technology (Oakes, 1990).

Although women have been entering the **work** force at an increased rate since the end of the Second World War, they often occupy lower status, nontechnical jobs in the service sector of the economy. One of the major labor supply challenges for the United States over the next two decades is to develop a balanced work force possessing the technical skills necessary for *jobs* in science *and* engineering. To do this. women will have to be integrated into thr technical and scientific secto's of the labor force to a far greater extent than *at* the present. Education, family, and occupation systems in the United States have consistently turned a majority of females away from science education. Many young girls who start out doing well in science end up with little scientific interest and knowledge. It is this training and education that provide the critical link between labor force needs and supply. What happens to the talented young women in this educational process? Recent work on educational systems suggest: that gender is one cf the major classifying characteristics in determining who will succeed and All high-level positions. This assumption is at the core of the conceptual framework used here.

The Conceptual Framework: Selection, Resources, and Lost Talent

Beginning with the work of Blau and Duncan (1967) and continuing in the "Wisconsin" model of status attainment (Sewell, Haller, & Chlendorf, 1970; Sewell, Holler, & Pones, 1969), the research on educational and occupational attainment in the United States has primarily relied on a functionalisl, socialization model (Horan, 1978) Tha: is, the research assumes that differences in attainment ran best be understood by differences in learned skills and motives, and thus that the attainment system offers a fair system of rewards to the most talented.

Prior to the introduction of Blau and Duncan's status attainment model, theoretical work in the United States and Europe focused more heavily on the structural factors tha- affected attainment, irrespective of individual merit (Kerckhoff, 1984). The inability of the status attainment model to explain equally **well** the achievements of blacks and whites, men and women, and upper class and lower class brought about a renewed interest in the structural impediments to achievement (Gicdens, 1973 Wright & Perrone, 1977; Pones & Wilson, 1976; Aexander & Eckland, 1974; Treman & Terrell, 1975). Theories focusing on **class** (Giddens. 1973), allocation (Kerckhoff, 1976), sponsored mobility (Timer, 1960), the regulation of ambition (Hopper, 1973), cultural capital @ourdieu, 1973), and segmented labor markets (Beck, Horan, & Tolbert, 1978) all questioned the ability to understand achievement without considering **social** structures.

These arguments about the import of nonindividual factors in social mobi ity systems suggest that there will he **a** considerable number of youth who **are** talented and motivated but who do not achieve because of their placement in the stratification system. In this research we are interested in exploring this "lost talent" among young women in scisnce.

The conceptual framework that is used here to approach the problem of talented young women exiting the sciences is one that stresses structural **barriers** or selection processes that directly affect science achievement though gender discrimination but that also indirectly affect science achievement through the transmission of "gendered" socialization and unequal allocation of resources in family and school environment;.

Kerckhoff(1976) and others have questioned the socialization model of achievement and argued that young people's expectations are not so much developed through the socialization **process** as through knowledge of the real world. Although everyone may want to succeed, people in different strata have different expectations as to their chances of success. For youth in more disadvantaged social positions, these expectations may start out hgh hut tend to be lowered over time as they observe *the* successes and failures of others like themselves (Han, 1969; Siegel, 1965; Kerckhoff, 1976; Oakes, 1985).

The link between position in the social structure and individual attitudes is discusred in **a** number of theoretical works on :he achievement process. Bourdieu (1973) suggests that societies reproduce themselves and maintain a system of power by means of the transmission of culture.

The reproduction of culture through education plays an important role in the reproduction of the whole system, and culture is arbitrarily imposed by dominant groups. Bourdieu suggests that education systems control mobility hy selecting out the students who will achieve. The selection process is one that assures the continuation of the status quo rif the system and is based on categories such as gender. race, and class. Those who are not in favor then begin to develop more negative attitudes toward school in anticipation of the barriers that confront them.

Other **work** on the role of sta us effects in educational systems is remarkably similar in noting the selection process and the anticipation of success reflected in students' attitudes. Kerckhoff (1976) discusses an allocation process whereby individuals are not free to achieve according to their talents **but** rather are subject to social forces that "identify, select, process, classify, and assign individuals according to externally imposed criteria" (p. 369). Students' expectations for their future are then affected by these observed con-[mints.

Further insights ino the notion of lost talent come from Turner (1960) and Hopper (1973). Turner made important contributions to our understanding of the role of structural **factors** in educational systems by distinguishing systems that allow free competition (contest nobility) from those that stratify early on (sponsorship mobility). Hopper (1973) added to this notion by stressing that societies need to be assured that high-level positions will he filled. They must, then, develop ambition in all youth. Through the process of selection by external criteria, some hut not all will succeed. Hopper suggests that societies must then "cool out" the ambition of the unsuccessful in order to avoid social conflicts. Education is a major vehicle in both the selection and the "cooling out" processes.

Little empirical work has been done on the intersection between status in the stratification system and **loss** of talent. Although there is **re**search that shows that the status attainment model works less well for women. blacks, and individuals from lower SES backgrounds (Portes & Wilson, 1976: Kerckhoff & Campbell, 1977; Alexander & Eckland, 1974; Treiman & Terrell, 1975; Treiman & Hartman. 1981 Rosenfeld, 1980; Sewell, Hauser, & Wolf, 1980), it often does not explicitly look at stratification status and the selection process. In my recent (1994) examination of lost talent among U.S. youths I found considerable loss of talent through mismatched aspirations and expectations and through reduced educational txpecrations. This loss varied with gender, race, and class.

One way to examine the selection process is to look at changes in expectations over time. Much of the evidence on women's educational exprctations suggests that women are more likely than men to adjust their educational expectations dowrward over time, especially with the advert of marriage and children (Haggstrom, Kanouse, &Morrison, 1986; Randour et al., **1982:** Marini, 1984). Research has shown that boys' educatioral aspirations anderpectations exceed those of girls, and that there is a greater consistency between the aspirations (hopes) and expectations among young nen than among youcg women (Crowley & Shapiro, 1982: Marini & Greenberger, 1978; Hanson. 1994). One of the few researchers who **has** not found gender differences in educational expectations and aspirations is Mickelson (1989). Her unique sample anc measures may he a partial explanation for her findings.

In Gaskell's (1985) study of working class females, she found that young women belirved that they were making personal educational choicss hut tha: those choices drew on real structures, and opportunities. The choices tended to reproduce class and gender structures, with the working class girls choosing nonacademic courses of study that would prepare :hem for derical jobs.

In sum, research on the general educational aspirations, expectations, and achievement of young people suggests that gender is an important factor in creating lost talent. What does thr research show about science education? Although it is clear that women are underrepresented in science, longitudinal examinations of the extent of lost talent and the process leading to it are rare (for exceptions see Oakes, 1990; Office of Technology Assessment, 1988; Rayman & Brett, 1993, 1995). The first goal of this research is to describe carefully women's and men's experiences in the sciences in order to assess the nature and extent of talent loss, especially among young women. But how does the lost talent process **work?** How are **talented** young women "cooled out"? Evidence from science research grounded in feminist theory and focusing on power and status in science occupations (Schiebinger, 1987; Rosser, 1987; 1990; 1992; Atkinson & Delamont, 1990; Rossi, 1964; Rossiter, 1982; Hollenshead et al., in press; Zuckerman. 1991; Fox, 1994, in press) and from the structural theories reviewed above *suggests* that inequalities hasec on gender are maintained hy differential treatment based on gender alone as **well** as by differential access to resources that favor young men over young women. The assumption is that different ties to the power structure creates gender stratification but that differential access to resources is necessary in maintaining rhe *stratification (Chafetz, 1984;* Giele, 1988). Although economic structure at he macro level will not be measured in this research the conceptual framework used here assumes that the differences in resources flow not from natural individual differences between the sexes but from gender differences in these ties. As the discussion below suggests, the family and school play a major role in redistributing resources that are potentially important for success ir science from the larger system to individuals. How does this process work?

Literature on Resources and Science

FAMILY RESOURCES. Family socialization and resource allocation are key ingredients in maintaining the sex stereotypes and norms that keep the gender stratification systrm intact (Parsons & Bales, 1955; Chodorow. 1978; Entwisle & Raker, 1983). Eeginning with birth, parents give children cues about appropriate gender-linked behaviors. These cues act as resources for children's later educational activities and interests. For example, mothers' communications with sons contains more of the verbal stimulation thought to foster cognitive development (e.g., explicit speech, and teaching and qurstioning that contain numbers and action verbs) than does their communication with daughters (Weitzman, Binns, & Friend, 1985). Boys and girls are given toys, clothing. physical environments, and rewards for two distirct types of behavior Boys are encouraged to he outgoing, aggressive, independent, and analytic, while girls are encouraged to be passive, dependent, and nurturent (Lake, 1975; McDonald & Parke, 1986; Fagot, Leinhach. & Kronsberg, 1985; Rheingold & Cook. 19751.

Likewise, parents encourage mathematical achievement more in boys than girls (Eccles & Jacobs, 1986) and accept lower mathematics achievement in girls than boys (Ndccohy & Jacklin, 1974). Parents hold different educational and career expectations for sons and daughters (Casserly, 1980), and these expectations influence those of their children (Armstrong & Price, 1982). Even parents of mathematically giked students have been found to view careers in mathematics as less appropriate for daughters than sons (Fox, 1980). These data are complemented by children's perspectives. Boys perceive their parents as being mnre positive about their mathematics achievement than girls do (Sherman & Fennema. 1978).

Research on women who succeed in science education and occupations shows that these women often had family ha-kgrounds that allowed them to develop independence in an environment with diverse role models. They tended to have families characterized by well-educated, parents, family stability, parental encouragement of androgyny and of achievement in science. and maternal employment. These women were also more likely than others to be first born (Smith. 1992; Mullis & Jenkins, 1988; Casserly & Rock, 1985; Auster & Auster, 1981; Rayman & Brett, 1995; Association for Women in Science [AWIS], 1993: Brown, 1990). Experiences in their family of procreation have also been found to be associated with women's entry intc and success in science. Women with husbands and with young children fare less well than do other women. These family experiences do not appear to work to the disadvantage of men in science (Shenhav & Hahcrfeld. 1988; Long, 1990; Pox, 1995, in press; Culotta. 1993).

SCHOOL RESOURCES. Three areas of school *influence have been stressed* in the science achievement literature—the "hidden curriculum," course taking. and peer influence. This literature shows how teachers, courses, and peers act as resources for achiwement in science. They stress gender differences in treatment and access that limit womens resources and accomplishments. Advocates of the "hidden curriculum' thesis propose that teachers hold different expectations for me two sexes, which they communicate in subtle hut pervasive ways. It has been shown, for example, that teachers give mare attention to boys than to girls (AAUW, 1992; Sadker & Sadker, 1986), invest more cognitive time with boys than with girls in mathematics (Brophy & Good, 1974) and science classes (*Morse & Handley*, 1985), and hold higher expectations of mathematics achievement for boys than for girls even before actual differences in achievement appear (Becker, 1981 Hallinan & Sorensen, 1987). Girls also receive less encouragement and information about courses and careers in math and science from high school guidance counselors (*Oakes*, 1990; Fox et al., 1985). And these teachers and counselors have effects on decisions that last well beyond the high school years (Ware & Lee, 1988). Teacher influence during the high school years also conies in the form of role modeling. for having womm science teachers in high school increases chances that a young girl will choose a science major in college (Matyas, 1986) and do better in college science courses (Boli et al., 1985).

The gender gap in science course taking has been well documented On average. girls and boys perform equally well in mathematics up to about grades 6 to 8; however, the number of females who continue to take nathematics course: drops precipitously during high school years (Office of Technology Assessment. 1988; Oakes, 1790; Fennema & Peterson, 1985), and this differential course taking in mathematics is found even when achievement and ability arc controlled (Fox, 1980) Further declines in science course raking among women occur in college. Won-en choose science majors at a much lower rate than do men (Commission on Professionals in Science and Technology, 1986; Oakes, 1990). One obvious implication, then, is that as early as junior high school females choose not to undertake the advanced [raining n math and sciencethat leads to careers in thr science and technical fields (Ernest, 1976. Sells, 1980). An additional loss occurs through lack of exposure to scientific thinking and, perhaps, leads to a lack of appreciation for the kinds of understanding scientific knowledge can provide (*Maccoby & Jacklin*, 1974). Women's knowledge and course taking in math are important resources for access to high-status occupations. Their lack of knowledge and course taking in math acts as a critical filter that keeps women out of a host of occupations, including chemistry, physics, engineering, computer science, and occupations in the social sciences and business that require an understanding of statistics (Sells, 1978, 1980). Numerous studies show the importance of gender differences in attitudes and achievement in math and science during high school for determining persistence in the scientific pipeline in the college, postsecondary and early work years. For example, interests and performance in college math and science courses are strongly linked to math course taking and achievement test scores in high school (Wise 1985; Ware & Lee, 1988: Boli et al., 1985; Wilson & Boldizar, 1990; Ethington & Wolfe, 1988).

Finally, we can think of the school peer group as a resource for young women's science achievement Studies have shown the importance of support from female friends for young women's continuation in science (Boswell, 1985; Fox, Tobin, & Brody, 1979). Peer group norms are at least part of the explanation for the success of single-sex girls schools in recruiting young women into math and science courses and. in general, in preparing women for nontraditional occupations (Fox *et al.*, 1985; Schwager, 1987; Tidball, *1980: Rice & Hemmings*, 1988; Lyall, 1987). Finally, a recent ethnographic study of college women showed that the peer group was a major factor in shifting young women's goals away from careers and interests in science and toward romance and heterosexual relationships (Holland & Eisenhart, 1991).

INDIVIDUAL RESOURCES. How do individual characteristics of young men and women affect their science experiences. and to what extent are they a product of the different resources allocated to men and women in school and the family? At the center of the research addressing these questions are the notions that institutions define gender roles and that these definitions become forged into a diffuse "gender belief system" that shapes the day-to-day behaviors and attitudes of men and women, boys and girls (Hess & Ferree, 1987).

Although boys and girls are equally likely to report that they like math (Ernest, 1976), math comes to be defined as a male preserve (Weitzman, 1979; Fox et al., 1985). Girls often fear that success in this male domain will make them less popular among peers (Fox et al., 1979). The content of courses may be important in conveying messages about girls' ability in mathematics. Early research showed that girls do more poorly on word problems based on male activities (e.g., woodworking and guns) than they do on the same problems put in the context of female-typed activities (e.g., cooking and gardening) (Milton, 1958). It is also interesting that girls' math **skills** improve when they are examined by other women (Pederson, Shineding, & Johnson, 1968).

There is ample evidence of the effect **of** cultural norms on women's perceptions of their abilities. For example, a number of studies have shown that students' achievement in math depends on its perceived usefulness to their future careers (Armstrong, 1985; Fennema & Sherman, 1977; Hilton & Berglund, 1974). Thus if girls do less **well** in math, it may he due to their implicit understanding that math skills will not be useful to then in their future family and **work** roles (Brush, 1980; Eccles et al., 1985), and, in fact, that the pursuit of professions that use there skills will conflict with their future family roles (Fox et al., 1985: Sherman, 1983). In both high school and college, women's identification with traditional sex roles and their perception of the incompatibility between science careers **and** family pursuits keep them from entering and persisting in the sciences. Men, on the other hand, do not see thr pursuit of math and science as bring in conflict with their Family roles (Matyas, 1986; Ware & Lee, 1988). In fact, women s perceptions of the career/family conflicts for women in science careers are probably accurate given the pressure for early productivity in these careers (Linn & Hyde, 1989).

Others cite the motive to avoid success **as** an explanation for women's lack of achievement in math and other areas of intellectual ability According to Homer's (1972) research, women want to succeed but are ambivalent about success in the context of social proscriptions concerning bright, **successful** women. However, replications of Homer's work have not reproduced tier results (Fleming, 1982: Condry & Dyer, 1976).

There is no reason to believe. then, that men and women differ in their basic motivations for success, hut the research stimulated by the fear-of-success concept his shown that individuals are iensitive to the social consequences of their achirvemrnt behavior and that these consequences are perceived as different for men and women in particular situations (Gravenkemper & Paludi, 1983).

Related to these social costs are the strong stereotypes held by young women. Many believe that math and science are more useful and important for and better understood by boys (Eccles et al., 1985; Zimmerer & Bennett, 1987). This stereotyping begins **as** early as the primary grades (Vockell & Lebonc, 1981).

Other personality characteristics that vary by sex and that have been shown to act as resources for achievement in science include confidence and self-esteem (Fennema & Sherman. 1977; Linn & Hyde, 1989); *sex* role altitudes (Farmer, 1976; *Crowley & Shapiro*, 1982); *educational*/occupational expectations (Hanson & Ginsburg 1988; Rosen & Aneshensel, 1978); and locus of control (Hanson & Ginsburg, 1988; Astin, 1974; Fennema & Sherman. 1977). These personal resources persist in their importance alter the high school years. DeBoer (1984b) found that one's perceptions of one's ability in science **and** one's attribution of success in science to ability were important predictors of participation and performance in science du-ing *college. Men have* the *acvantage on* borh of these.

Gender and Lost Talent: The Role of Discrimination

In sum, it is argued here that young talented women are more likely to leave the sciences than are young men because of structural barriers and viection processes. To some extent, the larger power structure is reproduced in the cultural milieus *of families and schools* that offer different experiences and resources to young women and men. But structural theories also argue that these experiences and resources cannot fully explain the differences in women's and men's achievements—in this case persistence in the science pipeline. Gender status in and of itself is ar. explanatory variable to the extent that equally qualified young women and men will not have equal opportunities in science. Discrimination based on gender *alone* **is** part *of the* reason for *young women's* **lack** of success in science

Kecenl **work** by Stockard (1985), Charles (1992), Hanson et al. (in press) and others dccuments the fact that women's advances in education (including science education) have not been met by similar advances in occupations. When Stockard looks at variation over time in the disparities between men's and women's education and income in the United Stairs, she finds that income *variations* are much larger and virtually unrelated to variations In education. Stockard concltdes that tie ultimate explanation for the continuing disparities in the occupational world cannot, then, be attributed to women's lesser training but instead most be assigned to cultural beliefs and practice; that give preference to males. Charles's 11992)examination of data on occupational segregation in the United States between 1950 and 1970 confirms Stockard's analysis. In the same *years that the economy* was developing and entering a postindustrial stage in which women obtained more education, Charles finds that occupational segregation increased.

Fox (1995; in press) provides further evidence for the importance of structural rather than individual factors in determining science achievement. She finds thatindividua characteristics involving *training and* family experiences have little explanatory power in understanding the gender gap in status and earnings in science occupations. There is a long history of research on women in science that suggests that structural impediments are a major factor in marginalizing women scientists (Cole, 1987;Zuckerman, 1991; Rossiter, 1982; Cole & Zuckerman, 1984).

Thus well-uained women contirue to experience barriers in the science occupations. The locse link be:ween women's access to education **and** occupations suggests that although education systems have been opening **up** to women, gender discrimination in the **work** arena continucs to consign them to low-status, law--paying occupations.

In sum, the research presented here utilizes a structuralist framework that suggests that gender will have both a direct and an indirect effect on science achievement. The direct effect will occur through discriminatory actiors and policies of key institutions that are based solely on gender, regardless of qualifications. Thr indirect effect will occur vis-à-vis the unequal resources offered to young women and men. This both insufficient resources as well as gender discrimination are explanations **for** the exiting of bright, talented women from the sciences.

The Study: Data and Methods

THE MODEL. The model used to guide this study of gender and lost **scientific** talent is presented in Figure 1-1. It borrows from the above literature on lost talent, status and resources, and the science pipeline. In general, the model shows thr different ways in which gender can affect science experiences and the relationships between key variables in the science achievement process. The time order of the ***kei*** factors in the mode is suggested by the left to right placement of the blocks of variables. with causation moving from left to right. All blocks of variables arc assumed to have direct eflects on science experiences. In addition, earlier variables can work through variables that occur between them and science experiences to affect these evperiences. Gender is exogenous in the model. It **is** thr status variable, which comes first in the process. Family and school resources and ultimately individual resources are endogenous variables, which come next. Finally, the model shows the outcome of interest—experiences in the sciences.

The model reflects several important characreristics of the science outcome. First, these experiences are multidimensional To understand the totality of science experiences fully, four dimensions must be considered: achirvrment, access, attitudes. and activities. Students may he high on some of these dimensions and low on others. Hence, focusing on a aingle dimension denies the multiple ways in which young people can experience science. **A** second important characteristic of the sdence pipeline is its longitudinal nature. Over time information on students in different stages in the pipeline is provided to describe these experiences. In addition, this causal model operationalizes experiences in each area of the science pipeline with trajectories that represent typical paths in an area over time.

The model presented in Figure 1-1 also reflects a number of characteristics of the causal process leading to experiences in rhe sciences. Most important is an acknowledgment of the different ways in which gender can affect science experiences. First, gender can have direct effects on

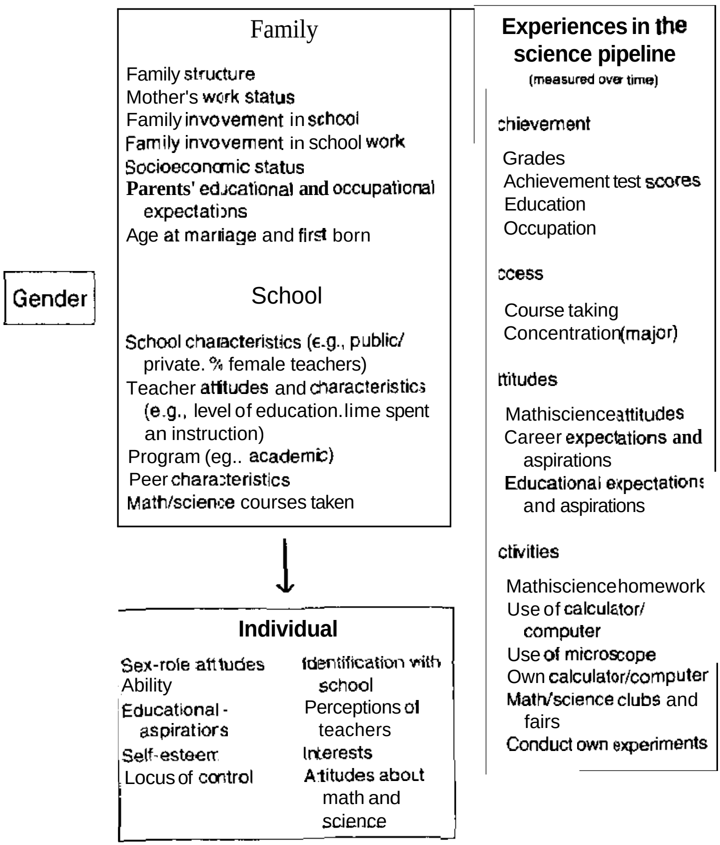

FIGURE 1-1 Model Predicting Lost Talent in the Sciences

these experiences, regardless of the family, school, and individual resources a student might have. Another important aspect of the effect of gender on science achievement is thar rhe effect of resources might be different for girls and boys (Both interactions and separate analyses for males and females are used to address this issue.) That is, girls may be less able to convert their family, school. and individual resources into science success than their male **peers.** Thus gender interacts with resources such that resources have different efiects for girls and bcys. This effect, togethsr with the direct effect of gender on science outcomes, can be classified as the *cost* of being in the female status. Thess effects represent gender inequality and discrimination since they involve differences in outcomes that are dependent only on the gender status, regardless of individual qualifications.

Gender can also indirectly affect experiences in the sciences by influencing important determinants of science experiences—resources on the family, school, and individual level. Gender differences in status and power are *legitimatized* by *cultural beliefs* and sex-role socialization that define science as **a** male realm and contribute to the unecual channeling of key resources. Young women then come to agree with these beliefs and develop individual acd personality characteristics that conform to them. Thus the model shows family and school resources preceding individual resources.

In sum, the model reflscts two ways in which gender per se can affect experiences in the sciences—a direct effect and an effect vis-à-vis its interaction with resources. Both are effects of gender status that occur in spite of individual talents and resources. The model also shows how gender can indirectly affect science experiences by affecting the level of resources allocated to younp girls and boys—resources that are critical for science achievement. **A** variety of statistical techniques will he used to assess thr model. Descriptive statistics will be **used** to show levels of resources and types of science experiences for young women and men Multivariate statistical models (including Analysis of Variance and logistic regression) fur the total sample and for subsamples of women and men will be used to show the effect of gender and resources on science experiences. (See the Appendix for derailed information on the measurement and analysis plan.)

DATA SETS. Thr empirical analysis in this research **will** focus on wailable longitudinal data sets involving large nationally representative Samples. These data sets allow assessment of the factors in our lost talent model and cover the years from grade 7 through early adulthood. during which youths might travel through critical education and early occupation segments of the science pipeline. The longitudinal nature of the data allows for clear assumptions about tine ordering of life events and the straightforward creation of trajectories. or over-time patterns of experience. The data sets are ideai for testing the model of gender and lost talent in the sciences.

Three data sets arc used. The first, High School and Beyond (HSB) contains data that were first collected in 1480 under .he auspices of the National Center for Ecucational Statistics (NCES, 1993). Base-year data collected in the spring of 1980 from approximately 58,000 high school sophomores and seniors were obtained from a multistage stratified cluster sample from 1,015 high schcols. They were interviewed again two, four, and six years later, providing information on high school experiences as well as early postsecondary and **work** experiences. KSB offers excellent measures of resource variables as well as science experiences. The sophomore cohon is of special interest since it is at this time that women begin falling out of the sciences. Given this and a need for parsimony, **the** causal model will be applied oily to the HSB sophomore ***co***hort. Only those individuals who participated in all phases of the study wire included in these analysts ($N = 11{,}683$). Note that those **who** dropped out of high school between grades 10 and 12 are not included in the sample. However. all analyses include weights that control for sample attrition and nonrrsponse. Important descriptive information on the nature of young women's and men's experiences in the sciences **will** be provided for all data sets.

The High School and Beyond data also include information from the teachers and principals **at** the students' high schools. We use data from the supplemental 1984 "Administrator and Teacher Survey" to provide information on teachers (gender, training. ratings, time spent on instruction, and influence on curriculum, content. and teaching technique) and schools (number of years of math and science required). Although the respondents were no longer in high schocl in 1984, he **NCES** argues that these data are still valuable since these school characteristics are fairly stable **over** time. The data come from a probability sample of 532 of the original 1,015 schools in the High School and Beyond survey. One principal from each school and up to **30** randomly selectcd teachers from each school were surveyed. The final **samples** incuded 402 principals and 10,370 teachers. Given the subsample of school: represented. we restrict our study of these data to descriptive analyses. Important information on teachers and schools is also included in the student component of the High School and Bcyond survey (see the Appendix).

The second **data** set, the National Educational Longitudinal Study (NELS), was begun **in** 1987–88 with a nationally representative sample of

26,200 eighth graders from 1,000 schools (National Center for Education *Statistics*, 1992). They *were interviewed* again two years later. Like rhe HSB, the NELS was collected under :hc auspices of the National Center for Educational Statistics, Its design is similar :o that used for the HSB. Thr NELS data are valuable for studying transitions from rniddlc school to high school.

The *HSB and* NELS data *represent* the best !age-scale, nationally *rep*-resenlafive information on the high school ant posthigh school years in the United Stater. They are two of the chief pol:cy instruments of the U.S. Department of Education.

Tie third data set used in this research is the Longitudinal Study of American Youth (LSAY), conducted by thr Public Opinion *Laboratory of* Northern Illinois University and funded by the National Science Foundation (Public Opinion Laboratory, 1992). Begirning in 1987 information was collected yearly from 60 seventh grades ard 60 tenth grades in a national probability sample of 52 middle schools and 52 high schools. The survey **has** a special focus on stucents' attitudes toward science and math. In this research, only the seventh-grade cohort is analyzed (given the tenth-grade HSB cohort analysis). The data used here include the years 1987 through 1990, which represent grades 7 through 10 for this seventh-grade cohort The **LSAY** data *set* will provide important information on experiences in the science pipeline during the middle *school* years and the first year of high school. It provides more detail on math and science experiences than any other data set.

The three nationally representative longitudinal data sets provide excellent measures of multiple science experiences and resources for critical years in the formation of young scientists. Descriptive and causal information gleaned from these data sets arc used to provide insights into the complexities of these science experiences ior women and explanations for the exiting of female talent from the sciences.