Pathways to a STEMM Career

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Abstract:

The selection of scientific and technical careers by American young adults has been and continues to be a major national concern. Using data from the 20-year record of the Longitudinal Study of American Youth (LSAY) and working within the social learning paradigm, this analysis uses a set of 21 variables to predict employment in science, technology, engineering, mathematics, or medicine (STEMM) at ages 34 to 37. The LSAY is the longest and most intensive longitudinal study of the impact of secondary education and post-secondary education conducted in the United States. A structural equation model found that mathematics is a primary gateway to a STEMM career, beginning with algebra track placement in grades seven and eight and continuing through high school and college calculus courses. Home and family factors such as parent education and parent encouragement of science and mathematics during secondary school enhanced the likelihood of a young adult entering a STEMM profession.

Keywords: science career choice, engineering career choice, longitudinal, LSAY, mathematics.

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From the launch of Sputnik in 1957 to today, there has been a continuing national discussion of the adequacy of the number of young people entering the scientific and technical workforce in the United States. Presidential commissions, Congressional committees, National Academy task forces, disciplinary societies, and business groups have studied the issue and produced a library of recommendations (The National Academies, 1993, 1999; NAE and NRC, 2005; NRC, 1999a, 1999b, 2001; NSB, 2006). *Rising Above the Gathering Storm* (National Academies, 2007) defined the flow of young adults into scientific, engineering and related fields as the key to the future prosperity of the United States. Failure to build and maintain a competitive scientific workforce in the decades ahead will inevitably lead to a decline in the American standard of living.

The Definition of STEMM Fields

The definition of the occupations and professions that should be included in an analysis of new entrants into the scientific and technical workforce is not simple. There is broad agreement that individuals who have earned a doctorate in a life science or physical science field and who use that degree occupationally belong in this group, and there is wide agreement that professional engineers are a part of this workforce. There is also general agreement that individuals with a degree in mathematics who use that training in their work should be included, although there may be some debate about whether a Ph.D. in mathematics employed by a hedge fund to build mathematical models should be included in the definition of the scientific and technical workforce.

There is less agreement about the inclusion of individuals planning a career in the health sciences. There is general agreement that physicians are members of the scientific and technical workforce, although only a small proportion of physicians engage in biomedical research in the same way as university-based biologists. The issue is less clear for pharmacists, nurses, optometrists, laboratory technicians, and various kinds of therapists.

One part of this problem is the role of research in the definition of membership in the scientific and technical workforce. If membership is limited to individuals whose work may contribute to the conduct of research or the direct creation of new knowledge, then most engineers would be eliminated as well as most health professionals.

This definitional problem becomes more difficult when we seek to look at the flow of young people into scientific and engineering careers. Although there is a justifiable interest in understanding the flow of young people into research careers, it is difficult to distinguish between future research scientists and future scientific and technical practitioners among high school students and college undergraduates. A few high school students can declare with some certainty that they plan to become a research scientist in a specific field, but far more high school and college students have never met a research scientist and tend to think of careers in terms of the professionals that they encounter in the course of their lives – teachers, doctors, nurses, lawyers, dentists – or indirectly through television and other media.

Given the limited exposure of most high school students to research scientists in any field, it is appropriate to define student interest in broader terms. Although many definitions of science, technology, engineering, and mathematics (STEM) careers have omitted the health professions, there is a strong argument for their inclusion. Many young people are exposed to physicians as patients and through television programs and may be attracted to the scientific nature of the work. The popular television portrayals of medical practice in an emergency room and as a part of a criminal forensics team often convey a sense of scientific exploration. This attraction to medical science may be important in causing a student to enroll in science courses in high school and to enroll in a pre-medicine program as a college freshman, but subsequent science courses may re-direct this hypothetical student into biochemistry, physiology, or other scientific or engineering fields. In this analysis, we utilize a broader definition and refer to STEMM (Scientific, *T*echnological, *E*ngineering, Mathematics, and Medical) careers.

Finally, within the broad realm of STEMM occupations and professions, it is useful to distinguish between professional STEMM occupations and more technical STEMM support positions. A good deal of the existing literature focuses primarily on professional STEMM careers, but an increasing number of STEMM studies that include community colleges describe a broad range of occupations as STEMM, but suggesting that these jobs require lower levels of formal education and often work under the supervision of STEMM professionals. For example, a medical laboratory technician with an associate degree is a STEMM worker, but will generally perform under the supervision of a pathologist with a medical degree or a laboratory director with an advanced degree in a scientific field. There are numerous examples in every aspect of science, technology, engineering, mathematics, and medicine. We have defined this second tier of positions as *STEMM Support* positions and will examine the pathways into those careers in other analyses.

Using these definitions, an analysis of LSAY participants in 2007 found that 6% of these young adults were employed in STEMM professions and an additional 7% were employed in STEMM Support occupations (see Table 1). This analysis will focus on the pathways to a STEMM profession and other analyses will examine the factors the lead to a STEMM Support career. All of the young adults who are employed as STEMM professionals have attained at least a baccalaureate and 39% have earned a doctorate or other professional degree. To understand the pathways that lead to a STEMM profession, it is necessary to utilize a two-step approach. First, we will utilize a sample of all LSAY participants during their secondary school years to identify the factors that lead to an initial enrollment in a STEMM program at the post-secondary level. Students who do not enroll in a post-secondary STEMM program have no chance of becoming a STEMM profession, thus we may think of this initial enrollment decision as the first major gateway into a STEMM profession. For this analysis, it is important to include all students in order to identify the factors that lead some students to enter the door and others to not enter.

Once enrolled in a post-secondary program, a number of other factors become important in fostering persistence and success at the baccalaureate, graduate, and professional levels. For this analysis, we will utilize only the records of students who initially enrolled in post-secondary education (PSE). We will include all students who enrolled in any field – regardless of its relationship to STEMM – on the grounds that these students could change their minds and switch into a STEMM field once enrolled in a PSE institution. Our analysis will show that this delayed entrance pattern is rare, but it is not zero and we will include the full PSE population in our analysis of the pathways from initial PSE enrollment to employment in a STEMM profession.

The construction of our analytic models was informed by the substantial literature on career development, and it is important to turn to a brief discussion of the major factors identified in earlier studies. A full review of this literature would be a book-length endeavor, but it is useful to acknowledge some of the major studies and paradigms that inform this work.

Previous Studies

There are a number of general models of career choice that include a full range of occupational choices, including the STEMM fields and other fields. Super (Super, 1957, 1980; Super & Bowlsbey, 1979) introduced the idea that career choice begins early and continues over the course of the life span. Although the majority of work in this field has focused on the experiences and influences that shape decisions early in life, Super provides an invaluable framework by asserting that individuals make career decisions throughout their lives in the form of decisions about the course of a career within a field and decisions about changing fields. Super's more than 40 years of work and his refinement of this basic idea is especially relevant today as technical revolutions in many industries have required workers to re-train and re-think career options at several points throughout their lives. The analyses reported herein reflect the life-span approach championed by Super and his collaborators.

Holland and his collaborators (Holland, 1973, 1985) viewed the career choice process as the product of basic personality and life preferences within the context of available options. Using the personality theory of his time, Holland identified six clusters of personality and work preference that have been translated into diagnostic testing instruments that are widely used in career counseling. Although few scholars in this area would assert that personality plays no role in the process, several empirical studies have found low or weak relationships between these constructs and actual career choices and thinking (O'Neil, 1977).

Building on broader social science constructs, Krumboltz and his collaborators (Krumboltz Mitchell, and Jones, 1976; Mitchell and Krumboltz, 1984, 1990; Krumboltz, 1994, 1996) have outlined a life-cycle framework that incorporates an array of social and contextual variables that reflect the flow of decisions and options that most individuals encounter during childhood, adolescence, and young adulthood. Referred to as a *social learning* approach, Mitchell and Krumboltz (1984) assert that:

> *Social learning theory* recognizes that humans are intelligent, problem-solving individuals who strive at all times to understand the reinforcement that surrounds them and who in turn control their environments to suit their own purposes and needs. (p. 236)

Krumboltz (1976), Farmer (1978), and Mihal, Sorce, and Comte (1984) offered multivariate models that described the role of parents, teachers, counselors, peers, media, and other factors on the development of career thinking and plans by adolescents and young adults. Rooney (1983) followed a sample of students three years after high school, building on earlier surveys of the same students by Farmer. Miller and Brown (1992a, 1992b) reported an early longitudinal model based on the first four years of the LSAY. The analytic models described in subsequent sections of this analysis utilize a social learning model to understand the sequence of experiences and decisions that shape career thinking from secondary school through young adulthood.

A number of studies have examined the development of student and young adult interest in STEMM careers, or in selected sets of occupations within the broader STEMM classification. Lent, Brown, and Hackett (1994, 2000) provided a useful integration of a wide array of career choice research into a summary model based on Bandura's social cognitive theory (Bandura, 1982, 1986, 1989, 1991). Dick and Rallis (1991) applied earlier models (Eccles, 1986; Meece, Parsons, Kaczala, Goff, & Futterman, 1982; Parsons, Adler, & Kacalal, 1982) to a large cross-sectional sample and found that science career choices for women more often were influenced by contextual and socializing factors than curricular experiences. Numerous studies have focused on the selection of careers in specific scientific or engineering fields. Most of these studies have attempted to link curricular changes in specific fields with the needs of the discipline and the interests of students (Duderstadt, 2008; Middleton, 2004).

Several authors have examined an early interest in STEMM careers using longitudinal data. Ethington and Wolfle (1988) used High School and Beyond (HSB) data to examine the factors associated with women majoring in a quantitative field two years after high school, and found the number of mathematics and science courses to be the most influential factor. Maple and Stage (1991) also used HSB data to examine the factors related to a quantitative major in college, and tested separate models for black females, white females, black males, and white males. Common to all of the groups was the significance of high school math and science courses and test scores.

Cross (2001) looked at the differences in perceived stress, support by academic department, and self-evaluations of abilities among graduate students in engineering and natural sciences at one university over a two year period, and found that there was no significant difference in ability, but that women rated their abilities lower than men. Farmer, Waldrop, Anderson, and Risinger (1995) re-interviewed 173 9^{th} and 12^{th} grade students from Illinois who had expressed an interest in a STEM career ten years later, and found that for women, persistence was related to the number of science courses taken in high school. Nauta and Epperson (2003) studied the aspirations of young women to become leaders in a STEM field using data from 204 young women who attended a high school STEM conference, and then re-interviewed them four years later.

More recently, several analysts have offered broad theories of career development, building on the metaphor of chaos theory (Bloch, 2005; Bright & Pryor, 2005), recognizing that individual decision-making sequences are frequently non-linear. Peterson, Krumboltz, and Garmon (2005) have re-conceptualized the social learning process within the context of both the chaos metaphor and the emerging information technologies.

Porfeli, Niles, and Trusty (2005) have provided a useful discussion of the major theories of career development over the last 50 years and have identified several common threads that run through all of these models. There is a broad recognition that career choice always involves some interaction between the perceptions and preferences of the individual which evolve and operate within social and institutional constraints. There is a general agreement that career plans and preferences develop over relatively long periods of time, with periodic reality adjustments, and that effective modeling of the process will require measurement over a number of years and, ideally, through several stages of life development.

METHODS

To fully understand the career development process, it is necessary to follow the same individuals along the path from secondary school into a college or university and frequently into graduate or professional schools. The data from the Longitudinal Study of American Youth (LSAY) provide a thorough empirical description of student experiences in middle school, high school, college, and graduate or professional schools and relevant life experiences during those years. To provide a comprehensive longitudinal examination of the development of student achievement in middle school and high school (and the relationship of those patterns to career choices), the National Science Foundation (NSF) funded the Longitudinal Study of American Youth (LSAY) in 1986. After a year of pilot testing instruments, the LSAY began collecting data from a national sample of 7th and 10th grade students in 50 public school systems in the United States in the fall of 1987. During the next seven years, each of approximately 5,900 students in the two national probability cohort samples were given mathematics and science achievement tests (based on the NAEP item pools) each fall and were asked to complete extensive attitudinal and self-report questionnaires each fall and spring. A summary of the major LSAY data collection activities is included in Appendix A.

In 2006, the NSF funded the resumption of LSAY data collection. Using available online tracking resources and previously collected parent and family contact information, it was possible to account for more than 95% of the original 5,945 students in the LSAY. Some of the students in the original sample are deceased, some were the children of foreign nationals who returned to their home country, and some were medically or mentally unable to continue participation. In addition, two of the original schools closed or were consolidated early in the study and it was impossible to continue data collection from those students, teachers, or schools. On the basis of a thorough search for all of the original LSAY participants, we were able to identify an *eligible sample* of 5,091 young adults (Kimmel & Miller, 2008). In the winter of 2007, each student in the eligible sample received a letter and questionnaire, covering their educational history and current and recent occupational history.

This analysis utilizes a consolidated data file (including both cohorts) that includes data from 3,547 participants (70% of the eligible sample) who completed the 2007 survey. The case file has been weighted to reflect the school and gender composition of the original LSAY sample and represents a weighted probability sample of public school students in 1987, with adjustments for death, illness, and migration out of the country.

The Flow of Young Adults into STEMM Professions

The pathway to a STEMM career begins at home. Decades of educational and social science research has documented the influence of parents on the formation of basic educational aspirations (Whiston & Keller, 2004; Heppner & Scott, 2004). Virtually all parents provide the first exposure of their children to language which provides the foundation for future learning in school and in society (Berger & Luckmann, 1966). Although schooling can expand and enhance a child's reading ability, the literature suggests that there are substantial differences in initial reading readiness and skills among children when they reach formal schooling and that many of these differences persist throughout school and beyond. Beyond language skills, parents convey important attitudes toward the value of education and the importance of achievement in a wide array of subjects and areas.

Some parents overtly encourage their children to engage in scientific, mathematical, and technological activities. This encouragement includes the selection of toys, the availability of devices from calculators to computers, and building things from either raw materials or pre-formed sets. Anecdotes about parents buying Lego sets for their infants in the hope that this early experience will stimulate an interest in science or engineering have their roots in real behaviors. Some parents utilize informal learning resources such as science museums, zoos, aquariums, planetariums, and similar facilities to introduce their children to interesting objects and to encourage and facilitate science learning. The cumulative effect of this smörgasbörd of home and community resources supplements formal schooling and provides some children with a substantial advantage in during their years of elementary and secondary schooling.

Children learn about science from a combination of school, media, and peer experiences. From kindergarten forward, children are exposed to a stream of lessons, films, field trips, and science fair projects that are designed to foster an interest in science and some acquisition of basic scientific concepts. Comparative international testing suggests that American students learn less science in school than comparable students in Europe, Japan, or numerous other countries (McKnight et al., 1987; Schmidt, McKnight, & Raizen, 1997; Schmidt, 2003). A full discussion of the factors that produce this result is beyond the scope of this analysis, but it is important to include school learning when we seek to understand the factors that lead some students to develop an early interest in a career in STEMM fields. Parallel to school experiences, students are exposed to a growing volume of television and motion pictures that include images of science and technology. The students in the LSAY in the late 1980's would have seen *E.T.* and had some exposure to *Star Wars*. They might have watched various television drama series built around medical forensics and may have first encountered the term DNA in a television crime story.

Although we know that children are exposed to a variety of images and ideas about science during their elementary and secondary school years, is there any evidence that these early events influence the eventual selection and pursuit of a career in a STEMM profession? There is substantial support for the impact of parent and home factors in the literature and the data from the LSAY provide a timely confirmation of the pervasive influence in parents in the system. At the most basic level, the likelihood that a young adult will enter post-secondary study is closely related to the level of the parents' education (see Table 2). Nearly half of the children of parents without a high school diploma (or GED) never enroll in post-secondary education (PSE), compared to only 8% of the children of parents with a graduate or professional degree. And young adults who do not seek a baccalaureate will not become STEMM professionals.

Although the career preferences of high school students often change in college and during young adulthood, it is useful to look at the expected college major of high school students as one of the first steps toward a STEMM career. High school career intentions are important because they inform many of the decisions that a student will make in regard to the selection of classes and the level of effort that he or she expends on specific courses and on academic work generally. Subsequent analyses will show that some of the high school students who express a preference for a STEMM career may migrate into non-STEMM fields, but very few students who did not plan to major in a STEMM field will migrate into these careers later in the process. With this pattern in mind, it is useful to look at some of the factors that are related to the intended college major of high school seniors.

Although the level of parent educational attainment is strongly related to entrance into post-secondary study (PSE), it is only moderate related to a student's intention to major in a STEMM field in college. Approximately 27% of the children of college graduates plan to major in a STEM field compared to 18% of parents with only a high school diploma (see Table 2). The LSAY data suggest that overt parent encouragement of college attendance and of science and mathematics are substantially more important factors. A measure of *parent college push* illustrates the power of parent encouragement. Only 4% of students who experienced low parent encouragement to attend college planned to enter a post-secondary program and major in a STEMM field, compared to 41% of students whose parents strongly encouraged college attendance. Overt parental encouragement of science and mathematics was equally influential. Only 11% of students whose parents provided a low level of science and mathematics encouragement planned to major in a STEMM field in college compared to 42% of the children of parents who provided strong math and science encouragement. In subsequent multivariate analyses, we will examine the role of each of these kinds of parental encouragement, but it is clear that the cumulative impact of these factors will be significant.

Elementary and secondary schools provide important instruction in and early exposures to science and mathematics. Schools vary in the scope and quality of their instruction and in the quality of teachers. The selection of a school reflects a mix of parent, community, and economic factors, but some parents overtly seek high-quality schools for their children within their geographic and economic limits. A thorough analysis of the school selection process is beyond the scope of this analysis, but it is important to recognize that parent and school resources are often related.

Within the school context, there are some important decision points. One of the most important is the timing of the initial study of algebra and the eventual completion of a calculus course during high school. In the late 1980's when the LSAY was initiated, approximately 14% of students took their first algebra course in grade eight and 47% started algebra in grade nine. Another 28% would take an initial algebra course in grades 10 or 11, but 11% of high school students in those years were never exposed to algebra. The timing of the initial algebra course is important because the hierarchical structure of mathematics instruction – geometry, second-year algebra, pre-calculus, and calculus – makes it difficult for students who do not begin algebra in grade eight to complete calculus in grade 12. In practice, the sorting of students into algebra tracks constitutes the primary form of high school tracking in the United States and is a strong predictor of subsequent enrollment in honors courses and advanced placement courses in all subjects. It is no surprise that the proportion of high school seniors who expected to major in a STEMM field was positively related to the timing of the initial algebra course (see Table 2).

We also note that there are some differences by race and ethnicity in plans to prepare for a STEMM career. As numerous other studies have found, Hispanic-American, African-American, and Native American students are significantly less likely to enroll in PSE at all and the small sample sizes for these groups make other comparison perilous. From other multivariate analyses, we know that a substantial portion of the race and ethnicity differences shown in Table 2 are accounted for by differences in parent education, home resources, and differential school experiences. Because of these limitations of our sample, we are not be able to provide a separate analysis of the impact of race and ethnicity on the selection of a STEMM career, but we feel obligated to at least note the disparities shown in Table 2.

Although high school juniors and seniors hold sincere expectations about their future college plans, the literature documents significant slippage between intentions and actual PSE enrollment. In the broader framework of adolescent socialization and development, this is not surprising. The transition from high school requires an extensive application process, potential re-location from the parental home for the first time in a young person's life, and securing resources to finance four or more years of post-secondary study. It may involve the disruption of social networks and close personal relationships. It is a rite of passage for many young people, and it is a very important gateway on the path to a STEMM profession.

Using most of the same variables that we employed to look at intended college major, we turn to a quick examination of the factors associated with initial post-secondary enrollment in a STEMM field. For this purpose, we count both community college enrollments and senior college enrollments when the student has selected a STEMM field. One in four LSAY students enrolled[1] in a PSE program in a STEMM field, a small increase from the 22% that reported an intention to enroll in a STEMM field during their last year of high school (see Table 3). The small number of cases involved precludes a definitive analysis of the factors associated with this change, but we suspect that it is linked to the superior counseling and advisory services available at the post-secondary level.

Most of the parental, family, and school factors associated with the intention to major in a STEMM field were associated with actual enrollment in a similar manner. The level of parent education was largely unrelated to enrollment in a STEMM field, but the level of parent college push and the level of parent encouragement of science and mathematics were positively related

[1] In most cases, the enrollment occurred the year following the completion of high school, but in some cases, the student may have deferred initial enrollment for a variety of reasons, including military service. One of the advantages of a longitudinal study that spans a number of years is that we can examine the behavior of interest regardless of its timing.

to PSE enrollment in a STEMM field (see Table 3). And student placement in a secondary school algebra track continued to be a powerful predictor of initial PSE program enrollment.

The bivariate relationships shown in Tables 2 and 3 provide a general sense of the structure of the pre-college life experiences and suggest some of the ways in which they factors influence the selection of an initial career path. Although we can look at each of these factors in separate tables, they occur simultaneously in the life of a student or young adult. It is conceptually and analytically important to try to estimate the relative influence of these pre-college factors before turning to an analysis of college and young adult experiences that may influence entrance into a STEMM profession. For this purpose, we will utilize a structural equation model to predict initial enrollment in a STEMM program at the post-secondary level. We include the full LSAY population in this analysis so that the results will be applicable to all secondary school students.

A Multivariate Model to Predict Initial Enrollment in a STEMM Program

A structural equation path model is a useful device for estimating the relative influence of each factor in models that include several factors. In broad terms, a structural equation model is a set of regression equations that predict each variable in the model and take advantage of our knowledge about the chronological or logical order of the variables. In a traditional least-squares regression model, all of the independent variables are treated as occurring at the same time and the regression seeks to determine the unique contribution of each variable holding constant all of the other independent variables in the model. But in real life, we know that all variables do not occur at the same time and it is analytically important to take into account the known order of predictor variables. For example, we know that parental educational attainment precedes the educational experiences and attainment of a child. A child's gender may influence his or her educational opportunities, but educational experiences cannot change the gender of the child. Of necessity, the placement of a student in an algebra track in 8th grade precedes his or her enrollment (or non-enrollment) in a high school calculus course in grade 12, and all of those experiences necessarily must precede admission to a college program or enrollment in college science and mathematics courses. The world is structured and we should take advantage of our knowledge of those structures to understand the pathways to a STEMM profession.

To understand the relative impact of several important family and school variables during the pre-college years, we have constructed a relatively simple path model (see Figure 1). In a path model, influence and causation flow from left to right and variables on the left side of the model are presumed to precede variables to their right either chronologically or logically. A detailed description of the construction of each variable in the model is included in Appendix B, and we will provide a summary description as we discuss the analysis of this and subsequent models. The model was estimated using LISREL 8.8 (Hayduk, 1987; Jöreskog & Sörbom, 1993).

For readers not familiar with this approach, it may be helpful to discuss briefly the logic of this analytic tool. Building on the basic idea that some variables occur prior to others in life and there is a known direction between those variables, the model in Figure 1 includes student gender, parent education, and parent employment in a STEMM field on the left side of the model, indicating that these factors were determined at birth or early in life and are not influenced by any other variable in the model. The frequency of parent encouragement of science and mathematics during high school may be influenced by the level of education of the parents or possibly by the gender of the child.

The results show that there is a relationship (represented by an arrow and called a path) between parent education and parent science-math push, with a path coefficient of .30 (see Figure 1). All of the paths shown in the model are significant at the .05 level or better. This path and coefficient indicates that parents with higher levels of educational attainment were more likely to encourage their child to do well in science and mathematics in high school than parents with lower levels of education. The path from gender to parent science-math push (.11) means that LSAY parents provided slightly more encouragement to their sons to study science and mathematics than they provided for their daughters, holding constant the level of parent education and parent employment in a STEMM field (Hayduk, 1987). And the absence of a path from parent employment in a STEMM field to parent science-math push indicates that parents who work in a STEMM field did not provide significantly more or less encouragement to their child to study science and mathematics than parents not employed in a STEMM job. These socialization behaviors are consistent with earlier studies by Parsons, Ruble, Hodges, & Small (1976). In this analysis of pre-college factors, the full LSAY participant population is examined using a total of 2,911 young adults who had data for each of variables in the model.

This path model demonstrates that a complex combination of factors contribute to each individual's decisions leading to enrollment in a post-secondary STEMM program (see Figure 1). As our review of the descriptive statistics in Tables 2 and 3 demonstrated, most students did not enter post-secondary programs in a STEMM field and approximately one in five students did not attempt any post-secondary program. Our analytic task is to identify and estimate the factors that cause some LSAY students to enroll in a STEM program others to make different choices.

A careful review of the numerous paths in the model in Figure 1 would reveal many interesting insights into the interaction of the several variables included in this analysis, but one of the advantages of using structural equation models is that we can obtain accurate summary measures of the *total effect* of each of the variables in the analysis. Some variables in this model have a combination of positive and negative effects, and the total effect is the net effect of the variable on our outcome variable – enrolling in a STEMM field at the post-secondary level. For example, the data in Figure 1 show that the parents of LSAY students provided more encouragement and more home learning resources for their sons than their daughters, but high school girls tended to have higher reading scores than high school boys, which provides numerous advantages in school programs and courses. When all of these advantages and disadvantages are combined, the results show that male students were slightly more likely to enroll in a STEMM program than female students, controlling for all of the other factors that occurred during the secondary school years, with a total effect of .04 (see Table 4). This result is consistent with our observations of the enrollment data from Table 2, but it provides a more accurate estimate of the net effect of gender when a wide range of other factors are held constant. For reasons of clarity and simplicity, we will focus most of our analysis on the total effects found in this pre-college model and subsequently on post-secondary effects in a second model.

Looking at the total effects of the variables included in our model to predict initial enrollment in a post-secondary STEMM program, the major predictor is a student's intention to enroll in a PSE

STEMM program during high school (.60). This result is consistent with the early socialization hypothesis outlined above. The relatively strong influence of parental encouragement of science and mathematics during the secondary school years (.19) supports the early socialization hypothesis. The low effect of parent employment in a STEMM field on initial enrollment in a STEMM field (.03) is not inherently in conflict with the socialization hypothesis, although we expected parents who are employed in the scientific workforce to have provided substantially more encouragement than parents outside that workforce.

The modest net influence of gender (.04) illustrates the complex interactions of family and school in the socialization process. The path diagram indicates that parents provide slightly more encouragement to their sons to do well in science and mathematics than they do for their daughters (.11). Parents also provided slightly more home science learning tools and toys for their sons than their daughters (.05). The model indicates that parents were even-handed in encouraging college preparation and entrance. High school girls scored higher on a standard reading test than boys (-.09), but boys scored higher on a science achievement test than girls (.08). High school girls reported that they received more encouragement from their math teachers than boys (-.06). There was no difference between boys and girls in their placement in the algebra track. High school boys were more likely to report that they liked math (.12) than were girls. On balance, boys and girls each received some encouragement or advantage from some aspects of their home or school experiences, but it was a mixed set of experiences and the modest total effect suggests that the much larger gender effects found in the 1960's and 1970's were beginning to erode in the early 1990's.

The substantial influence of mathematics – and especially calculus – on initial enrollment in a STEMM program in science or engineering is shown in the paths in Figure 1 and the total effects for non-medical enrollment in Table 4. The total effect of taking a calculus course in high school on the likelihood of enrolling in a STEMM post-secondary program was .27. Initial algebra track placement was positively related to initial enrollment in a STEMM field (.09), but this relationship was weaker because the critical decision point turned out to be completion of a year of high school calculus. The initial algebra course was an important step toward calculus, but a substantial number of students who took algebra in grade eight did not eventually enroll in high school calculus. It is important to note that the total effects in a structural equation model are cumulative; the combined impact of algebra track placement (.09), student achievement score in mathematics in grade 12 (.09), and completion of a year of high school calculus (.27) was .45.

The pre-college model accounted for only 36% of the total covariance in enrollment in a STEMM field (see Table 4). Although the proportion of covariance explained was lower than we would have expected, the fit statistics at the bottom of Table 4 demonstrate that this is a good fitting model.

A Multivariate Model to Predict Employment in a STEMM Profession

The preceding analysis looked at the factors associated with enrollment in a post-secondary program to prepare for a STEMM profession. The pathway to any STEMM career begins with post-secondary enrollment in an appropriate program, but it is important to understand the factors that are associated with the completion of that program and – in many cases – graduate or professional training that are required for entry into a STEMM profession. Having obtained some understanding of the factors that help form initial interests and plans, we turn to an analysis of the factors that predict successful entrance into a STEMM.

In the LSAY post-secondary population, 8% of young adults were employed in a STEMM profession in 2007 (see Table 5). Young men were three times more likely to be employed as a STEMM professional than were young women. The children of better-educated parents were significantly more likely to be employed as a STEMM professional than the children of less-well-educated parents, and the influence of parent encouragement to attend college and to study science and mathematics were strongly associated with employment in a STEMM profession. The importance of taking algebra in grade eight continued to be a major predictor of entrance into a STEMM profession. And the number of undergraduate calculus courses was strongly related to employment in a STEMM profession.

To determine the relative importance of these factors on entrance into a STEMM profession, we expanded our previous model to include the number of college calculus courses and the number of college science courses completed during the undergraduate years and we added variables to mark the completion of a baccalaureate program in a STEMM field and the completion of a graduate or professional degree in a STEMM field, as well as our new outcome variable – employment in a STEMM profession. Because of the complexity of the previous model and limited number of cases of STEMM employment in this sample, this second model will drop some variables that were found to be unimportant in the preceding analysis. The path diagram in Figure 2 shows all of the paths from the earlier pre-college variables that link directly to one of our post-secondary variables but does not show all of the secondary school paths reported in the previous model. The total effects of each of the variables included in the expanded model are shown in Table 6 and those computations reflect all of the paths among the pre-college variables even though they were not re-drawn in Figure 2.

Looking at the extended model, employment in a STEMM profession is the product of early parental encouragement, early algebra, high school calculus, college calculus, and a combination of appropriate undergraduate and graduate degrees (see Figure 2 and Table 6). Although the magnitude of early parental encouragement is weaker some 20 years after middle school or high school, they still retain a significant cumulative impact. The total impact of parent education, parent college push, parent math-science encouragement, parent employment in a STEMM field, and home science learning resources was .24.

The long-term influence of algebra-track placement (.08) reflects its role as a gate keeper to high school calculus (.28) and eventually college calculus courses (.31). Cumulatively, early student access to mathematics and subsequent persistence and success in mathematics are essential gateways to a STEMM profession. In some STEMM fields (engineering, physics, and chemistry, for example) high school calculus is a prerequisite for admission to a PSE program and in other STEMM fields the completion of at least one year of college calculus is a requirement for a baccalaureate. Although the importance of mathematics and calculus have long been recognized, there has been relatively little attention to the early decision points that have a substantial impact of the likelihood of successful entrance into a STEMM profession.

High school and college science courses have small positive effects on planning for and eventually entering a STEMM profession, but at every level the relative influence – measured by total effects in these models – is smaller than mathematics. Although many programs and institutions place a lot of emphasis on trying to increase student interest in science these models suggest that student attitude toward – or liking – science is not a significant positive or negative factor in influencing successful entrance into a STEMM profession.

Employment in a STEMM profession requires the acquisition of credentials, and our model documents the importance of earning a baccalaureate in a STEMM field (.47) and a graduate degree in a STEMM field (.39). The completion of a graduate degree is not important for initial employment in engineering and it is this differential in initial requirements that reduces the total effect associated with a graduate or professional degree. But for many STEMM professions, a graduate or professional degree is a minimum requirement.

Gender is an important influence in the final determination of employment in a STEMM profession, but its influence varies over time and in ways that run counter to some of our expectations. Although a substantial literature in the 1960's and 1970's documented parental and teacher encouragement of boys in science and mathematics more than girls, the data from the LSAY paint a somewhat different picture. As shown in several tables and in both models, there were only minor differences between parental and teacher treatment of boys and girls in secondary school and the advantages and disadvantages associated with gender was mixed. A higher proportion of young women entered post-secondary study than young men and there were only small differences in the completion of baccalaureate programs in STEMM fields in the aggregate, although there are much larger differences in some fields such as engineering. Yet, between the completion of a baccalaureate and employment in a STEMM profession, the number of young men entering a STEMM profession grows to three times the number of young women. In a separate analysis, Clewell, Kimmel, & Cosentino (2010) examine this transition in greater detail, but it is important to note that the employment outcomes that were observed for these young adults in their mid-30's involve a complex set of educational, professional, family, and personal relationships that appear to remove a significant number of young women from the pathway into a STEMM profession.

This model to predict STEMM employment in the total LSAY population accounted for 50% of the total covariance (see notes on Table 5). It is useful to note that this model incorporated primary family and school socialization variables and post-secondary course-taking and degree completion. It did not include health, family, or attitudinal variables. Using the results of this analysis, we will simplify this model by eliminating variables are have minimal or insignificant effects and add ore family and attitude variables in future analyses, but the size of the LSAY sample places some limitations of the number of variables that can be entered into any specific model. We think of this model as a baseline model that describes the major structural characteristics of the pathway to a STEMM profession.

DISCUSSION

This analysis demonstrates that the pathways to a STEMM career are long and complex, as Super, Krumboltz, and others suggested they would be. To enter a STEMM occupation, a student must successfully negotiate a series of educational gates over a period of years while sustaining interest and focus. Too often, cross-sectional studies have focused on short-term influences, but this longitudinal record indicates that many factors have early roots and long-term impact (Paa & McWhirter, 2000; Turner & Lapan, 2002). The patterns reported in these models using data collected over a 20-year period could only have been found in a longitudinal model. We report this model as a baseline for a continuing series of analyses of the factors that influence employment in a STEMM profession.

The primary points that emerge from these analyses are (1) the continuing importance of home and parental factors, (2) the central role of mathematics in becoming a STEMM professional, and (3) the substantial gender difference in employment in a STEMM profession that emerges late in the process and that appears to be largely unrelated to curricular or credentialing issues.

For the last several decades, studies of the scientific workforce have pointed to the lack to racial and economic diversity and recommended programs to foster greater access to STEMM programs for women and for racial and ethnic minorities. Some programs have attempted to address the underrepresentation of new STEMM professionals from less-advantaged economic backgrounds, and many of the programs originally designed to serve the needs of minority communities have inadvertently addressed this issue. In the decades after the *Bakke decision*, many universities have re-cast programs to address economic disadvantage.

The LSAY model to predict initial STEMM enrollment at the post-secondary level demonstrates the continuing disparities associated with parent education and its related influences. The children of less-well-educated parents were markedly less likely to enroll in post-secondary education of any kind, which is an automatic disqualification from potential STEMM employment at the professional level. Better-educated parents were more likely to recognize the importance of science and mathematics and to encourage their children to appreciate and learn about science through overt encouragement and indirectly through science-related books, materials, and toys. The gradual weakening of the influence of these early factors over the 20 years of the LSAY reflects both the importance of individual student decisions and the degree of discretion that most American parents give to their children in making career choices. Nonetheless, these models demonstrate the continuing truth of the observation that young adults from advantaged family backgrounds are disproportionately represented the STEMM professions.

The second major finding from these analyses is that mathematics is the gateway to a STEMM career. The completion of a calculus course in high school and the number of college calculus courses were two of the strongest predictors of STEMM employment in young adulthood. Traditionally, calculus was viewed as a prerequisite for engineering, physics, and chemistry, but today it is emerging as important in genetics and bioinformatics. Almost all undergraduate and graduate programs in science treat calculus as a prerequisite and students and faculty see calculus and related courses as important contributors to higher scores on undergraduate and graduate admissions tests.

The model to predict initial post-secondary enrollment in a STEMM field identified early secondary school algebra tracking as a primary influence on high school math achievement, high school science achievement, and the completion of a calculus course during high school. All of these factors were positively related to initial PSE enrollment in a STEMM field. Unfortunately, this critical decision point continues to be largely invisible to most students and parents and perhaps to teachers and school administrators. Despite the strong recommendation of the National Council of Teachers of Mathematics nearly 20 years ago that a majority of students should begin algebra in grades seven or eight, there has been limited progress in this area.

Finally, these models point to the continuing importance of gender in understanding successful entrance into a STEMM career. The pre-college model identifies several points at which gender is an important influence, beginning with parental attitudes and encouragement. High school boys report slightly more parental encouragement to study science and mathematics than girls (.13), but high school girls – perhaps with parental encouragement and attention – score higher on reading tests and female students are more likely to earn a baccalaureate than male students. In the post-secondary model, female students were more likely to earn a baccalaureate than males, but male college students were slightly more likely to earn a baccalaureate, graduate, or professional degree in a STEMM field than female students. Yet, by their mid-30's, young men were three times more likely to be employed as a STEMM professional than young women. It is clear that neither the pre-college experiences not the post-secondary program experiences of the young men and women in the LSAY would predict this kind of disparity in actual employment. This result suggests that other factors that were not included in this model must account for the significant reversal of fortune for young women headed toward a STEMM profession. In other analyses, we will examine what we currently know about the possible influence of personal and family factors on these decisions and we will attempt to monitor this pattern in future cycles of the LSAY, building on the work of Rosser (2004) and others.

Setting aside this serious gender disparity momentarily, what are the programmatic implications of the findings in regard to social class disparities and the role of mathematics on entrance to a STEMM profession? Neither problem is simple and neither problem will yield to easy short-term solutions. But there are some things that can and should be done.

Efforts to address disparities associated with parent education and social class must begin with a sustained focus on the pre-college years and must include both parents and children. Programs like those at the Lawrence Hall of Science recognize the need for family involvement and the critical role of mathematics in preparing young people to prosper in the 21st century in STEMM jobs or other fields. Although there have been numerous attempts to replicate and expand programs similar to those at the Lawrence Hall, professional educators and educational leaders have a clear preference for programs that can operate within the public schools (and now charter schools) and that do not involve extensive parental or neighborhood involvement. Many of these out-of-school programs have had positive results, but in the longer term it will be beneficial to link these programs into school systems in ways that will preserve critical elements of their independence and vitality.

The algebra tracking problem is simpler in many ways – more and more schools have demonstrated that it can be done effectively – but it is inherently linked to the preceding problem of differential parental and family resources. When the child of better-educated parents has difficulty understanding an algebra concept or problem, he or she asks one of their parents to help. But a child in a family in which no parent has ever encountered algebra will find no help at home and perhaps little in the neighborhood. More than 20 years ago, Robert Moses identified the class differential in algebra as an important civil rights problem and founded The Algebra Project, with funding from the McArthur Foundation and later the National Science Foundation. Despite the good work of The Algebra Project in numerous communities (see www.algebra.org), there is a need to energize both the resources of school systems and the drive of parents to provide early and effective exposure for all students regardless of their parents' education or resources.

The first step in solving any problem is to understand the problem. We hope that these initial models are helpful in demonstrating the complexity of the pathways that lead to a STEMM profession and the feasibility of meaningful interventions to improve both the flow of young people into STEMM professions and the diversity of that flow.

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Appendix A: The Longitudinal Study of American Youth (LSAY)

To fully understand the career development process, it is necessary to follow the same individuals along the path from secondary school into a college or university and frequently into graduate or professional schools. The data from the Longitudinal Study of American Youth (LSAY) provide a thorough empirical description of student experiences in middle school, high school, college, and graduate or professional schools and relevant life experiences during those years. To provide a comprehensive longitudinal examination of the development of student achievement in middle school and high school (and the relationship of those patterns to career choices), the National Science Foundation (NSF) funded the Longitudinal Study of American Youth (LSAY) in 1986. After a year of pilot testing instruments, the LSAY began collecting data from a national sample of 7^{th} and 10^{th} grade students in 50 public school systems in the United States in the fall of 1987. During the next seven years, each of approximately 6,000 students in the two national probability cohort samples were given mathematics and science achievement tests (based on the NAEP item pools) each fall and were asked to complete extensive attitudinal and self-report questionnaires each fall and spring.

One parent of each LSAY student was interviewed each spring by telephone, and all of the mathematics and science teachers who served one or more LSAY students were asked to complete a questionnaire for each course, including information about the objectives of the course, the textbook used, and the allocation of time and effort in the course to various kinds of instructional activities. The principal of each participating school was asked to complete a school questionnaire periodically. When the initial period of data collection ended in the spring of 1994, the LSAY data set included approximately 7,000 items for each student, including 13 points of measurement for the 7^{th} grade cohort.

In 2006, the NSF funded the resumption of LSAY data collection. Using available online tracking resources, it was possible to account for more than 95% of the original 5,945 students in the LSAY. Some of the students in the original sample are deceased, some were the children of foreign nationals who have returned to their home country, and some are medically or mentally unable to continue participation. In addition, two of the original schools closed or were consolidated during the course of the study and it was impossible to continue data collection from those students, teachers, or schools. On the basis of a thorough search for all of the original LSAY participants, we were able to identify an *eligible sample* of 5,091 young adults (Kimmel & Miller, 2008).

In the winter of 2007, each student in the eligible sample received a letter and questionnaire, covering their educational history and current and recent occupational history. The questionnaire collected information about changes in marital and family status and some measures of life goals. Each participant was offered the option of completing the questionnaire online, on paper, or in a telephone interview and was offered some financial compensation for their time and effort. Respondents were offered compensation for completing the questionnaire, with an average payment of about $30.

This analysis utilizes a consolidated data file (including both cohorts) that includes data from 3,547 participants (70% of the eligible sample) who completed the 2007 survey. The case file has been weighted to reflect the school and gender composition of the original LSAY sample and represents a weighted probability sample of public school students in 1987, with adjustments for death, illness, and migration out of the country.

Appendix B: Variables and Scales Used in Analysis of Pathways to STEMM Careers

The following variables are used in the tables presented in this analysis or in one or both of the structural equation models included in this analysis.

Variable or Scale	Definition and Construction
Student Gender (male)	This baseline variable was collected as a part of the original sample selection process and was confirmed at various points over the years of data collection. For use in this model, gender was treated as a *dummy variable* – coded as zero and one – and male respondents were assigned the higher value.
Parent education	This variable reflects the highest level of education attained by either parent. It is a composite variable constructed from multiple inquiries to one or both parents in telephone interviews during the time that the student was enrolled in middle school and high school. For single parents, the education of the single parent is used for the parent education variable. In a small number of cases, a parent interview was not conducted (due primarily to the refusal of the parent to be interviewed) and in those cases, the LSAY student was asked to report the level of education of his or her parents. Parent education is a four-level categorical variable: less than high school, high school diploma or GED, baccalaureate, or graduate or professional degree.
Parent employment in a STEMM occupation	Using the same combination of parent interviews described above, each parent was asked about his or her occupation and this variable is the coded result of analyzing each reported occupation. Seven percent of LSAY parents were employed in a STEMM occupation and 14% were employed in a STEMM Support occupation.
Parent college push	This variable is designed to reflect the level of parent encouragement of a student to prepare for and attend a college or university. The basic questions ask each parent how much education that they would like their LSAY student to complete in his or her lifetime and how disappointed they would be if the student did not complete that educational level. Parent college push is a five-level ordinal variable.
Parent science-math push	This variable is constructed from student reports about various parent activities and behaviors, including six items that involve parental encouragement of science or mathematics. The responses have been collapsed into a six-level ordinal variable.
Home science learning resources	This is a count of the number of science learning resources that each student reported were available in his or her home. Some of the items – especially computers – were confirmed in parent telephone interviews. This variable is entered into the model as a seven-category ordinal variable.

Student reading score	Each LSAY student was asked to complete a reading test as a part of in-school testing. The reading test was composed of passages that were originally used in Coleman's High School and Beyond Study or the NCES National Educational Longitudinal Study of 1988. Item-response-theory (IRT) methods (using BILOG-MG) were used to compute an interval reading score that ranges from zero to 100.
Algebra track	Several previous analyses have found that the year in which an individual completes his or her first-year algebra course is a good indicator of placement in a mathematics tracking system (Hoffer, 1992; Oakes, 1985, 1990). It is an ordinal variable with three levels: (1) no algebra course in high school or algebra in grade 10 or later, (2) algebra in grade 9, and (3) algebra in grade 7 or 8.
Science teacher push Mathematics teacher push	Separate variables were computed for each high school science or mathematics teacher, using student reports about the kinds and frequency of teacher encouragement to study science or mathematics in high school and to continue studies of science or mathematics in the future. A summary scale was constructed for all science teachers and all mathematics teachers experienced by each student during his or her high school years. Each summary scale is an ordinal variable ranging from zero to five.
Student attitude toward science Student attitude toward mathematics	During secondary school, each LSAY student was asked each year how much they liked the subject matter of each course in which they were enrolled, using an A-to-F grade card format. Using the responses for science courses and mathematics courses – summed across the secondary school years – separate measures of student attitude toward science and toward mathematics were constructed. Separate five-level ordinal variables were entered into the model for liking science and liking mathematics.
Student mathematics achievement score	A set of achievement tests were developed using the full item pools from the National Assessment of Education Progress (NAEP). The first year achievement tests were comprehensive, but subsequent tests were tailored to three levels of achievement to obtain a more accurate measure of achievement. For this model, the mathematics achievement score obtained in the fall of the senior year is used as an indicator of student achievement in mathematics. IRT methods were used to construct an interval variable that ranges from approximately zero to 100.
Student science achievement score	Using the NAEP item pool, a separate science achievement test was constructed and administered in the early fall of each school year. Using IRT methods, an interval measure of student science achievement is used in this model that ranges from approximately zero to 100.
Student expectation of a STEMM major in college	This variable was collected annually during high school and the senior-year response is included in the analysis as a dichotomous variable.

Student calculus course in high school	This variable indicates whether or not each student completed a year of high school calculus. This indicator is entered into the model as a dichotomous variable.
Initial enrollment in a post-secondary STEMM program	This variable is constructed from a set of responses provided in 2007 to describe all educational activity since high school. It is a dichotomous variable with a value of 1 for any student that initially enrolled in a community college or a senior college or university.
Number of undergraduate calculus courses completed	This variable is a count of the number of calculus (or higher) mathematics courses completed during undergraduate study. The variable is entered into the model as an interval variable.
Number of undergraduate science and engineering courses	This variable is a count of the number of science, engineering, and technology courses completed during the undergraduate years. This variable was entered in to the model as an interval variable.
Completion of an undergraduate degree in a STEMM field	This dichotomous variable indicates whether or not each individual earned a baccalaureate degree in a STEMM field.
Completion of a graduate or professional degree in a STEMM field	This dichotomous variable indicates whether or not each individual earned a graduate or professional degree in a STEMM field.
Employment in a STEMM profession	This dependent variable is a measure of employment in a STEMM profession 13 to 17 years after high school graduation. It is a dichotomous variable.

Table 1: STEMM Employment and Level of Education of Respondent, 2007-8.

	% of all Students	Level of Education					
		LT HS	HS	AA-AS	BA-BS	MA-MS	PhD/Pro
STEMM*	**6.0**	**0%**	**0%**	**0%**	**38%**	**23%**	**39%**
Scientists	.5	0	0	0	0	32	68
Engineers	2.0	0	0	0	52	31	17
Medical Professionals	1.7	0	0	0	3	9	88
Other STEMM Professions	1.8	0	0	0	67	23	10
STEMM Support*	**6.9**	**0**	**25**	**23**	**31**	**13**	**8**
Other Health Workers	4.5	0	18	21	31	17	13
Other Technicians	2.4	0	38	26	32	4	0
Non-STEMM	73.3	4	51	4	26	11	4
Out of Workforce/No Resp.	13.7	7	57	6	24	5	1
All LSAY Respondents	100.0	4	47	5	27	11	6
N =	3,547						

* Excludes social scientists. To adjust to include social scientists, add .2 to the STEMM total and .7 to the STEMM Support total and subtract .9 from the Non-STEMM line.

Table 2: Distribution of High School Student Plans to Major in a STEMM Field in College.

	Expected college major		No PSE	N
	STEMM	Non-STEMM		
All LSAY Respondents	22%	56%	22%	3,539
Student Gender				
Female	20	61	19	1,737
Male	24	51	25	1,802
Parent Education				
Less than high school	8	45	47	233
High school graduate	18	53	29	1,614
Some college	24	56	20	492
Baccalaureate	27	62	11	634
Graduate or professional	28	64	8	544
Parent College Push				
0 (low)	4	37	59	278
1	15	49	36	500
2	22	59	19	1,377
3	29	60	11	999
4-5 (high)	41	55	4	227
Parent Science-Math Push				
0 (low)	11	52	37	577
1	14	60	26	541
2	17	60	23	675
3	20	62	18	950
4-5 (high)	42	45	13	796
Algebra Track				
No algebra course in HS	3	34	63	361
Algebra I in grades 10-12	14	57	29	957
Algebra I in grade 9	27	60	13	1,631
Algebra I in grade 8	40	56	4	461
Race/Ethnicity				
Hispanic American	16	52	32	288
African American	28	44	28	309
Asian American	42	56	2	117
Native American	16	51	33	49
Other American	22	57	21	2,574

Table 3: Student Enrollment in a Post-secondary STEMM Program.

	PSE Enrollment in ...		No PSE	N
	STEMM	Non-STEMM		
All LSAY Respondents	25%	53%	22%	3,539
Student Gender				
Female	22	59	19	1,737
Male	27	48	25	1,802
Parent Education				
Less than high school	15	38	47	233
High school graduate	23	48	29	1,614
Some college	28	52	20	492
Baccalaureate	25	64	11	634
Graduate or professional	32	60	8	544
Parent College Push				
0 (low)	12	38	59	278
1	17	47	36	500
2	26	55	19	1,377
3	30	59	11	999
4-5 (high)	33	63	4	227
Parent Science-Math Push				
0 (low)	17	46	37	577
1	16	58	26	541
2	21	56	23	675
3	26	56	18	950
4-5 (high)	38	49	13	796
Algebra Track				
No algebra course in HS	11	27	62	361
Algebra I in grades 10-12	18	53	29	957
Algebra I in grade 9	29	58	13	1,631
Algebra I in grade 8	38	58	4	461
Race/Ethnicity				
Hispanic American	22	46	32	288
African American	28	44	28	309
Asian American	39	59	2	117
Native American	34	33	33	49
Other American	24	55	21	2,574

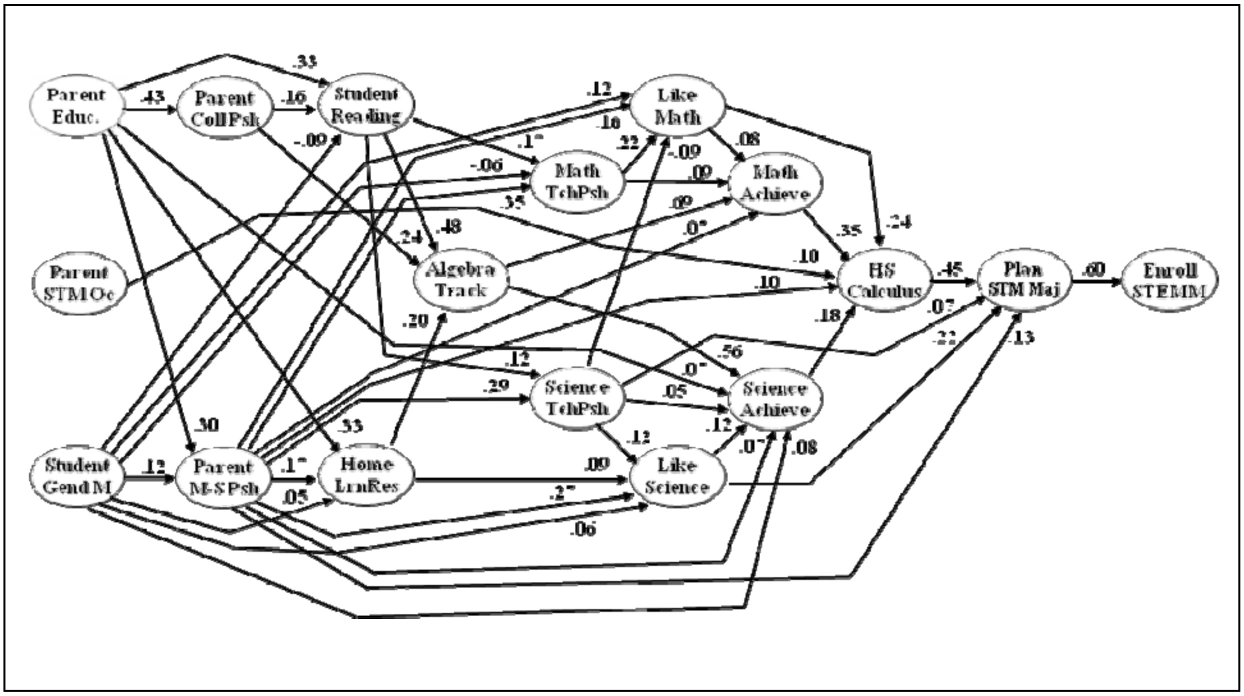

Figure 1: A Path Model to Predict Enrollment in a Post-secondary STEMM program.

Table 4: Total Effect of Variables Predicting Initial PSE Enrollment in a STEMM Major.

Variables in Model		STEMM Enroll
Gender	Student gender (male)	$.04_{(.01)}$
Home and family	Parent education	$.10_{(.01)}$
	Parent employment in a STEMM field	$.03_{(.01)}$
	Parent college push during high school	$.03_{(.01)}$
	Parent math-science push during high school	$.19_{(.02)}$
	Home science learning resources	$.03_{(.01)}$
	Student reading ability in high school	$.05_{(.01)}$
Secondary schooling	Student algebra track middle and high school	$.09_{(.01)}$
	Science teacher encouragement HS	$.06_{(.02)}$
	Mathematics teacher encouragement HS	$.02_{(.00)}$
	Student liked science as a subject in HS	$.14_{(.02)}$
	Student liked mathematics as a subject in HS	$.07_{(.01)}$
	Student science achievement score, grade 12	$.05_{(.01)}$
	Student math achievement score, grade 12	$.09_{(.01)}$
	Student completed calculus course in HS	$.27_{(.03)}$
	Student planned to major in STEMM in college	$.60_{(.03)}$
	R^2 =	.36

Fit statistics: Degrees of freedom = 83; Chi squares = 1934.8 (p = .00);
Root Mean Square Error of Approximation (RMSEA) = .045;
90% confidence interval $_{(RMSEA)}$ = .041; .048; N = 2,839

Cell entries: $.18_{(.02)}$ Each cell entry is the total effect for that variable on the outcome variable.
The standard error of each total effect is shown in parentheses.

Table 5: Young Adult Employment in a STEMM Profession.

	Employed in ...			Not Employed	N
	STEMM Profession	STEMM Support	Other Occupation		
All LSAY Respondents	8%	9%	71%	12%	2,752*
Student Gender					
Female	4	9	67	20	1,403
Male	12	9	75	4	1,349
Parent Education					
Less than high school	0	14	75	11	124
High school graduate	5	10	72	13	1,155
Some college	5	8	74	13	394
Baccalaureate	11	9	68	12	566
Graduate or professional	15	9	67	9	504
Parent College Push					
0 (low)	0	9	78	13	115
1	3	9	72	16	322
2	7	10	70	13	1,116
3	11	9	69	11	889
4-5 (high)	17	7	69	7	214
Parent Science-Math Push					
0 (low)	2	7	78	13	364
1	3	7	78	12	398
2	5	9	75	11	516
3	7	9	70	14	779
4-5 (high)	16	11	62	11	693
Algebra Track					
No algebra course in HS	0	2	79	19	134
Algebra I in grades 10-12	1	8	76	15	677
Algebra I in grade 9	8	11	70	11	1,420
Algebra I in grade 8	19	7	65	9	441
Number of College Calculus Courses Completed					
None	3	9	74	14	1,848
One or two courses	12	11	68	9	573
Three or more courses	37	8	48	7	249

* This table includes only respondents who enrolled in a community college or senior college.

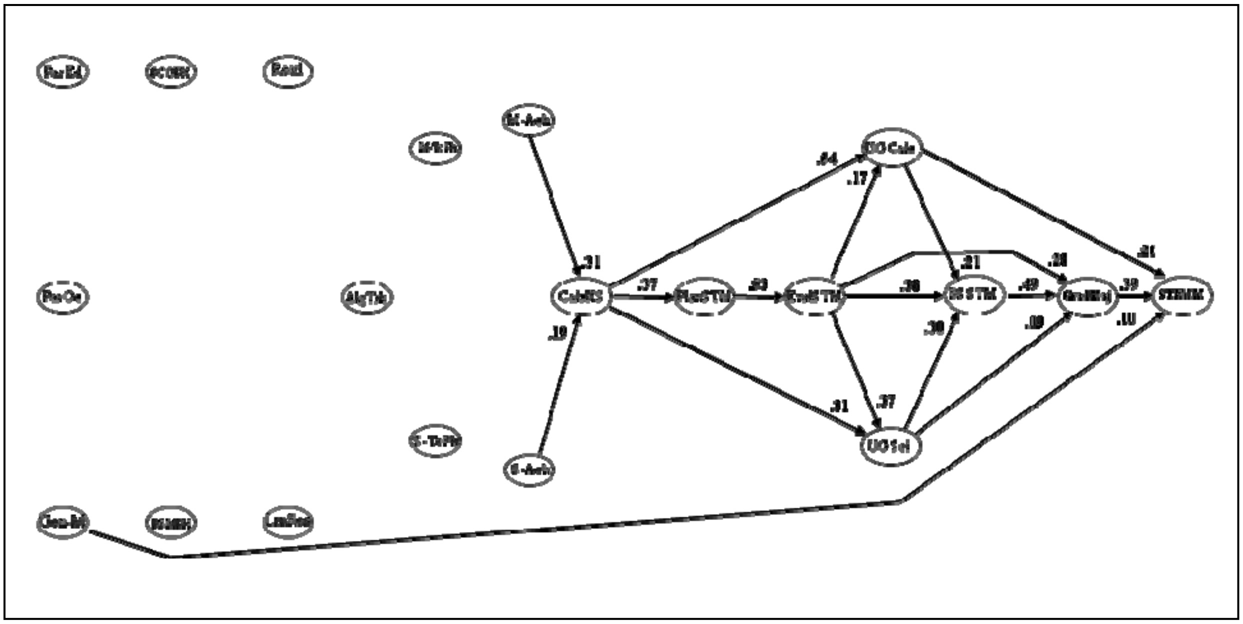

Figure 2: A path model to predict STEMM employment at age 33-37.

Table 3: Total Effect of Variables Predicting STEMM Employment.

Variables in Model		Total Effects
Gender	Student gender (male)	$.13_{(.02)}$
Home and family	Parent education	$.06_{(.01)}$
	Parent employment in a STEMM field	$.03_{(.01)}$
	Parent college push during high school	$.02_{(.01)}$
	Parent math-science push during high school	$.11_{(.01)}$
	Home science learning resources	$.02_{(.00)}$
	Student reading ability in high school	$.05_{(.01)}$
Secondary schooling	Student algebra track middle and high school	$.08_{(.01)}$
	Science teacher encouragement HS	$.00_{(.00)}$
	Mathematics teacher encouragement HS	$.03_{(.00)}$
	Student liked science as a subject in HS	$.04_{(.01)}$
	Student liked mathematics as a subject in HS	$.08_{(.01)}$
	Student science achievement score, grade 12	$.05_{(.01)}$
	Student math achievement score, grade 12	$.09_{(.01)}$
	Student completed calculus course in HS	$.28_{(.03)}$
	Student expectation of STEMM major grade 12	$.16_{(.02)}$
Undergraduate experience	Student initial enrollment in PSE STEMM program	$.29_{(.02)}$
	Number of student college calculus courses	$.31_{(.04)}$
	Number of student college science courses	$.17_{(.02)}$
	Student undergraduate major in STEMM field	$.47_{(.04)}$
Graduate	Student graduate degree in STEMM field	$.39_{(.05)}$
	R^2 =	.50

Fit statistics: Degrees of freedom = 164; Chi squares = 2219.9 (p = .00);
Root Mean Square Error of Approximation (RMSEA) = .039;
90% confidence interval $_{(RMSEA)}$ = .036; .042; N = 2,232

Cell entries: $.18_{(.02)}$ Each cell entry is the total effect for that variable on the outcome variable, employment in a STEMM field. The standard error of each total effect is shown in parentheses.