Are We Missing Opportunities to Encourage Interest in STEM Fields?

The disciplines of science, technology, engineering, and mathematics (STEM) have experienced problems in producing adequate numbers of graduates to meet workforce needs in these fields. Although entrance into the STEM fields has grown, this growth is not keeping pace with the overall needs of the labor market (CPST, 2007; Lowell & Regets, 2006). Since 2001, a decline in the share of total employment in STEM areas has been seen (CPST, 2007). A report by the Commission on Professionals in Science and Technology (CPST, 2007) notes that, while our nation's workforce is growing in these fields, it still lags behind the overall growth of the United States, resulting in a serious deficit in the supply side of the STEM workforce. From 2001 to 2006, STEM employed professionals declined from 5.6% to 5% in the United States. This decline mirrored post-secondary enrollment in STEM degree fields (Ashby, 2006). While the actual enrollment in STEM degree fields increased from 519,000 students in 1994-1995 to 578,000 students in 2003-2004, the proportion of undergraduate degrees awarded in STEM fields actually declined from 32% to 27 % of all degrees awarded. This decline has significant economic implications, since the United States needs to produce more graduates in the STEM fields to maintain its competitiveness in technological areas (COSSA, 2008).

Better understanding of the important influences in career considerations is crucial to help guide interventions aimed at improving career access in the STEM fields. As noted by the CPST report (2007), we are at a critical position in regard to the future workforce in STEM areas, and we need to address why these fields are not attracting future professionals and the influence this may have on the long-term global competitiveness of our nation. Reports indicate that, on average, there are 200,000 vacant engineering positions annually in the United States (Machi, 2008). Machi (2008) notes that the United States is graduating roughly 60,000 engineer students annually in comparison to China and India, where both countries produce approximately 600,000 annually. The United States is currently ranked 20th in the world in the proportion of students earning a four-year degree in engineering or natural science (Kuenzi, 2008). Students in the United States are far less likely to earn a four-year degree in engineering or science than students in other countries (AAU, 2006).

Cathy Hall (hallc@ecu.edu) is a Professor in the Department of Psychology at East Carolina University; Jeremy Dickerson (jdickers@coastal.edu) is an Associate Professor in the Spadoni College of Education at Coastal Carolina University; David Batts (battsd@ecu.edu) is an Associate Professor in the Department of Technology Systems at East Carolina University; Paul Kauffmann (kauffmannp@ecu.edu) is a Professor in the Department of Engineering at East Carolina University; and Michael Bosse (bossem@ecu.edu) is an Associate Professor in the Department of Mathematics, Science, and Instructional Technology at East Carolina University.

Numerous studies have been conducted on factors influencing students' choice of major (Beggs, Bantham, & Taylor, 2008; DeMarie & Aloise-Young, 2003; House, 2000; Kuechler, McLeod, & Simkin, 2009; Malgwi, Howe, & Bunaby, 2005; Schwartz, 2004; Tan & Laswad, 2009). Studies have identified personal interest as a key factor (Beggs et al., 2009; Kuechler et al., 2009). In a survey of 852 college students, Beggs et al. (2009) identified various factors influential in choice of major with interest in a field being rated as the most important influence. Other contributing influences cited by college students were parents, friends, relatives, professors/teachers, and counselors. Job characteristics were also influential and included factors such as beginning salary, earning potential, benefits, and advancement. Other areas included factors related to the major/degree such as ease in earning degree, faculty reputation, and introductory course. The researchers noted that, while the student's own interest was the highest rated influence in considering a major, this required having knowledge of that area. If a student has never been exposed to a particular area, then interest cannot develop.

If we are not attracting sufficient numbers of students into STEM careers, what factors might be influencing consideration of these fields? The purpose of the study was to ascertain what factors were influential in developing an interest in career options among high school students. The study further sought to determine the knowledge of school personnel and parents about STEM careers, since they are often cited as key influences in students' choice of major (Malgwi et al., 2005). Last, the study sought input from current college students completing an engineering program on when they had made a decision to pursue their current major and the factors that influenced their choice. Our central research questions were: (1) How did high school students rate various factors in influencing their interest in career options? (2) Given past research citing the influence of parents and school personnel on students' consideration of a field of study, what knowledge of STEM fields did these individuals have? (3) Were the influences reported by high school students similar to the reported influences of college students majoring in engineering? and (4) When did college engineering students report deciding on a major? Through this study we hoped to provide a more integrative summary of factors influencing the choice of STEM fields, engineering in particular.

Methods

High School Participants

One hundred thirty-two high school students—ranging in age from 12 to 18 (mean age of 14.6) and ranging in grade from freshman to senior (61 students for summer of 2007 and 71 students for summer of 2008)—were extended invitations to attend the Information Technology Academy for Students (ITAS). Seven students were unable to attend after accepting the invitation, and six students left before the end of the three-week ITAS academy. One hundred

nineteen students were in actual attendance for the entire three weeks of the academy. One male student failed to complete the survey leaving a data set of 118 students—63 (53.4%) female students and 55 (46.6%) male students. The race/ethnicity of the students was as follows: American Indian 2 (1.7%), African American 52 (43.7%), Pacific Islander 1 (0.6%), Asian 2 (1.7%), Hispanic/Latino 15 (12.6%), Caucasian 42 (35.3%), and other 5 (4.2%). Three of the students were rising eighth graders, 16 students were rising high school freshmen, 61 sophomores, 31 juniors, and 8 seniors.

High School Student Survey

A two-part questionnaire was used to ascertain the influence of various factors in students' consideration of career options. Part A of the questionnaire focused on specific influences on career choices and the student's interest in career options. This part asked students to rate 10 specific influences on their career considerations using a five-point Likert scale from 1 (*no influence*) to 5 (*very strong influence*). The areas of influence included factors such as friends, peers, parents, teachers, counselors, the media, degree options, earning potential, and affordability of college program. The second part of the questionnaire (Part B) asked students to rate how important five factors were in developing their current career interests from 1 (*not important*) to 5 (*very important*). This section included factors such as having friends with same interest, someone in their family who was working in a particular field, having a teacher who encouraged them about a field, and having someone at their school that was knowledgeable about different career options. The questionnaire for the current study was based in large part on a previous NSF project (Gross, 1988) that identified key factors in encouraging students in mathematics (i.e., good teachers, school personnel, negative teachers, peers, home environment). Research by Malgwi et al. (2005) that cited student interest, earning potential, peers, parents, and school as influential in encouraging students to consider a career field, also significantly influenced the development of the current questionnaire.

Parent Participants

Parents of potential academy students were asked to complete a brief, anonymous survey regarding their aspirations for their sons/daughters. One hundred eighty-four parents completed the surveys. The majority of respondents were mothers (67.9%), followed by fathers (21.7%), other relative (i.e., grandparent, aunt, uncle; 6%), foster parent or guardian (2.7%), and both parents completed (1.1%). Of the responding parents, 43.5% were African-American, 42.4% Caucasian, 1.6% Native American, 0.5% Asian, and 12% Hispanic or Latino. Fifty-two percent indicated they were the parent of a daughter, and 48% indicated they were the parent of a son. Regarding grade level, 66.1% indicated their son/daughter was a freshman in high school, 23.9%

sophomore, 5.6% junior, and 3.9% senior. Approximately 90% of parents/guardians indicated they had graduated from high school, with 66% indicating they had received some post-secondary training.

Parent Survey and Procedure

Symposiums were held for the parents of potential academy students at each of the participating school districts/high schools in the spring of 2007 and 2008. Not all parents of potential academy students were in attendance, and some parents attended whose son/daughter did not attend the academy. The focus of the symposiums was to make parents aware of the academy, the selection process, the potential benefits for their sons/daughters, and address any concerns they might have in allowing their sons and daughters to attend a residential program on a college campus.

In addition to demographic questions (i.e., race/ethnicity, relationship to parent/guardian's highest level of education), parents were asked how far they wanted their son/daughter to go in school and how often they talked with their son/daughter about courses, grades, plans post-high school, jobs/careers, college entrance exams, and application to college. They were also asked how much they knew about college/university admission procedures; financial aid for college; careers in different fields; and specifically knowledge of careers in science, math, engineering, and technology.

High School Personnel Participants

Thirteen high school math teachers, 12 science teachers, and 8 school counselors (12 men and 21 women) completed a survey regarding their knowledge about careers in the STEM fields in January of 2007 to aid in developing information for the NSF grant. Math and science teachers in five rural school systems were asked by their school administration to participate. Forty-two surveys were sent to teachers at the schools agreeing to participate in the summer academy, and 33 completed surveys were returned. The average time in the teaching profession of those completing the survey was nine years (range 1 to 27 years). One of the goals for our grant was to make STEM careers more of an option for consideration by rural high school students. In order to assess where efforts might be most beneficial in regard to the grant, this part of the study was conducted to better understand the current knowledge of and encouragement by school personnel about the STEM fields at the high school level. Three different concentrations (math, science, and school counselors) were chosen to match the identified groups that the grant would be working with during the academy.

High School Personnel Survey

Teachers were asked to rate on a four-point Likert scale—ranging from 1 (*strongly disagree*) to 4 (*strongly agree*)—their knowledge about careers in

scientific fields in general and, specifically, their knowledge about careers in information technology (IT) and engineering (i.e., "I feel that I am very knowledgeable about careers in ___").

College Student Participants

Eighty-three students enrolled in an introductory course for engineering majors, and 24 seniors who were scheduled to graduate at the end of spring semester 2008 (this represented the first graduating class for a recently implemented engineering program) were surveyed. Of the 83 students beginning the program, 72 were male and 11 were female with a mean age of 21.03 (range 18-37 years). Seven students were African American, 2 Asian, 2 Hispanic/Latino, 69 Caucasian, and 3 designated biracial. Of the 24 seniors, 21 were male and 3 were female with a mean age of 22.42 (range 21-30 years). One student was African American, 21 were Caucasian, and 2 indicated biracial.

College Student Survey

The survey was the same as administered to the high school students with the addition of one question: "When did you decide on engineering as your career choice?" The decision to participate or not participate was voluntary, and there was no penalty for choosing not to participate. Given the low retention rate in some of the STEM fields (House, 2000; Morton, 2007; Tsui, 2007), it was felt that surveying both entering and exiting students would provide more valid information, as well as possibly pinpointing any difference between those who were retained and those who were not.

Research Protocol

The research protocols were approved by the university's Institutional Review Board (IRB) and conformed to American Psychological Association (APA) ethical guidelines for research with human participants. The decision to participate was voluntary for all participants, and there were no penalties if anyone chose not to participate. In order to obtain consent with high school students, parents completed a consent form for their son/daughter to participate in the study, and the son/daughter completed an assent form as a minor as well. Both forms were required for the high school student's responses to be included in the study.

Results

High School Students

For Part A of the survey, high school students rated their interest in a field as the most important consideration in a career choice with their parents' influence as second. Third was the earning potential, and fourth in their ratings was the influence of a teacher (see Table 1). When next asked about the importance of various factors in the interests they have (Part B), the key

influence was the knowledge of school personnel about various fields, followed by having a teacher encourage a particular field. While students rated other factors relatively high, these were the primary areas noted as most influential in encouraging them to explore career options.

Table 1
Means and Standard Deviations for High School Students and College Students Reports of Career Influence (n = 225)

	High School Students (n = 118)	Freshmen College Students (n = 83)	Senior College Students (n = 24)
Part A: How much do you feel each of following influences your thinking about future career options?			
Friends	3.08 (1.21)	2.62 (1.09)	2.63 (1.01)
Parents	**4.21 (**1.05)	**3.79** (1.06)	**3.71** (1.23)
Teacher	**3.99 (**1.00)	**3.40** (1.12)	**3.38** (1.17)
Negative Influence of Teacher	1.96 (1.06)	2.00 (0.99)	1.35 (0.57)
Cost of Degree	3.50 (1.28)	2.88 (1.28)	2.43 (1.50)
Time to Degree	3.17 (1.26)	2.84 (1.21)	2.13 (0.92)
Earning Potential	**4.11** (1.04)	**4.08** (0.81)	**4.00** (0.72)
Interest in area	**4.62 (**0.74)	**4.44** (0.77)	**4.65** (0.57)
Stay in Region	2.46 (1.32)	2.28 (1.34)	2.43 (1.38)
Media	2.72 (1.22)	2.62 (1.16)	2.13 (0.92)
Part B: How important are the following to the career interests you currently have?			
Friend with Same Interest	3.43 (1.13)	**3.32** (1.06)	**3.63** (0.82)
Interest as Same (Gender) Friend	3.01 (1.11)	2.95 (1.09)	3.08 (1.10)
Occupation of Family Member in Field	3.05 (1.21)	2.59 (1.29)	2.25 (0.99)
Teacher Encouraging Field	**3.85 (**1.08)	2.81 (1.15)	3.25 (0.79)
Knowledge of School Personnel about Career Field	**4.10** (1.06)	**3.40** (1.17)	**3.67** (1.24)

Parent Survey

All the parents surveyed indicated that they wanted their son/daughter to obtain an education beyond the high school level. Of those parents responding to this question (181 out of 184), one parent indicated a vocational or technical school (0.6%), 39 (21.5%) indicated a four-year college degree, 37 (20.4%) indicated a master's degree of equivalent, and 104 (57.5%) indicated a PhD, MD

or other advanced degree. All had hopes that their child would pursue a degree beyond high school with the majority (77.9%) indicating they wanted their child to go beyond a four-year college degree. Certainly these parents are aware of the advantages of higher education and have high aspirations for their son/daughters.

The parents were then asked how frequently they interacted with their adolescent regarding school and future careers by responding to a series of questions based on a four-point scale ranging from 1 (*never*) to 4 (*5 or more times in past few months*). The responses are presented in Table 2. Parents reported valuing education and actively encouraging their son/daughter in school areas. While they also reported involvement in talking with their adolescents regarding preparing for college and applying to college, these two areas reflected relatively lower ratings possibly due to being less knowledgeable about these particular areas.

Table 2
Percent of Parent Responses Regarding Talking with their Adolescents about School and Careers (n = 184)

	1	2	3	4
Selecting school courses	0.6	11.0	35.4	53.0
Discussion about grades	--	1.6	12.6	85.7
What your son/daughter will do after high school	0.5	3.3	15.4	80.8
Discussion of jobs/careers	--	6.0	16.9	77.0
Discussion about preparing for college (i.e., entrance exam such as SAT)	4.9	13.7	30.2	51.1
Discussion about applying to college	0.5	12.6	25.1	61.7

(1 = *never*, 2 = *1-2 times*, 3 = *3-4 times*, 4 = *5+ times*)

The last series of questions asked parents to rate their knowledge about higher education processes, as well as their knowledge about jobs and careers, on a five-point scale ranging from 1 (*very little*) to 5 (*a great deal*). Results are presented in Table 3 (next page). As seen below, there are some areas where parents felt their knowledge was limited. In particular, the parents' ratings of their knowledge about science, math, engineering, and technology programs were weak in comparison to other areas they rated.

Table 3
Parental Knowledge about College and Career Topics

	1	2	3	4	5
Information about colleges	12.1	13.7	35.7	22.0	16.5
The college admissions process	14.8	19.2	28.0	19.8	18.1
Financial aid for college students	15.9	20.9	28.6	18.1	16.5
Jobs/careers in different fields	11.5	15.9	37.4	19.8	15.4
Information about science, math, engineering, or technology fields	25.6	27.8	32.8	6.7	7.2

(*1 'very little' to 5 'a great deal'*)

High School Teachers

Three areas emerged as concerns in regard to STEM fields from the surveys of 33 high school math (11) and science (12) teachers and counselors (10): 32.3% did not feel that they were knowledgeable about career options in scientific fields; 62.5% did not feel that they were knowledgeable about career options in information technology; and 61.3% did not feel that they were knowledgeable about engineering career options. Means and standard deviations for each of the three questions are presented in Table 4. Math teachers rated themselves slightly higher than science teachers or counselors in knowledge of careers in scientific fields, but all groups were consistently low in knowledge of careers in information technology and engineering.

Table 4
Means and Standard Deviations of Teachers' Knowledge of Careers in Fields of Science, Information Technology and Engineering

Source	Scientific Fields	Information Technology	Engineering
Math Teachers	3.15 (0.69)	2.23 (0.83)	2.23 (0.73)
Science Teachers	2.55 (0.69)	2.42 (0.79)	2.54 (0.69)
Counselors	2.84 (0.69)	2.34 (0.75)	2.36 (0.66)

1 (low) to 4 (high)

College Students

College students (both introductory and senior college students in engineering) completed the same questionnaire administered to high school students. Part A of the questionnaire asked what influenced them to think about a career in engineering, and their ratings closely mirrored those of the high school students (see Table 1). Interest in the field was rated the highest by both introductory and senior students, followed by earning potential, then parents, and high school teacher. Both high school students and college students were consistent in the top four rated influences, but the second and third highest rated influences were reversed for the two groups.

Part B of the questionnaire asked college students what factors influenced their interest in different careers. The highest rated influence was the knowledge of school personnel about career options, followed by having a friend with the same interest. One of the strongest reported influences was the same as it was for high school students, having someone in the school system that had knowledge of career options.

This study also asked the university students in engineering when they had decided upon engineering as a major, and 34.7% of the students in an introductory engineering course indicated after entering college, 55.1% indicated in high school, and 10.2% before high school. For the college seniors, 50.2% indicated the choice was made in college, 45.8% indicated the choice had been made in high school, and 4.2% reported earlier than high school. For both of these college groups, close to half reported that the decision to consider a major was made in high school.

Discussion

This study focused on the assessment of student influences on career choices and the knowledge of STEM career fields of students, parents, and teachers. The top four influences on career choice reported by students were personal interest, parents, earning potential, and teachers in that order. These results are consistent with other studies that have indicated student interest, parents, and teachers played significant roles in the development of career interests by students (Gross, 1988; Malgwi et al., 2005). While parents and teachers represented strong influences on consideration of potential careers, their knowledge of STEM occupations was found to be limited. This has the potential to seriously reduce students' consideration of STEM fields, especially in information technology and engineering. A catch twenty-two situation existed in that, while personal interest, parents, and teachers were rated as the top influences, students need to have knowledge about careers to ascertain if they are personally interested in a field. Without the support and encouragement of parents and teachers to explore options in STEM fields, many students may never even consider these fields.

Not all students enter college with a declared major and many students also change majors (Donnelly & Borland, 2002; Ohland et al., 2008). Ohland et al. (2008) reviewed extensive databases with information on over 300,000 first time students, covering nine institutions of higher learning. They found that 23% of these first time students entered college without a declared major. While many disciplines benefit from matriculation of this group, STEM fields, engineering in particular, do not, with less than 3% of these undeclared students matriculating into STEM fields. Ohland et al. (2008) go on to note that 93% of students enrolled in engineering after eight semesters also entered college with this same major, with other majors ranging from 35%-59%. While engineering had a high persistence rate compared to other fields (57%), they were not attracting

undeclared or change of major students. In comparison, over 40% of students majoring in computer science and other STM fields came from other majors. These findings strongly suggested introduction to these fields at the secondary school level is paramount if students are to be encouraged to pursue STEM fields, especially engineering.

It was also found that the responses of college students in engineering programs closely mirrored the same influences as reported by the high school students, with school personnel and teachers being cited as having a strong influence on their decision of major. There has recently been a greater emphasis on developing a STEM presence at the high school level through collaborative partnerships with the potential for building interest in and attracting students to STEM fields (Merrill, Custer, Daugherty, Westrick, & Zeng, 2010). The secondary school setting represents a critical point in helping adolescents become aware of potential STEM careers and connecting these career decisions to educational decisions.

Two primary influences on student decision-making, parents and school personnel, were found to have limited knowledge of STEM careers, especially in regard to information technology and engineering. Prior research indicates that parental influence is especially important to adolescents during the high school years in career considerations, and that adolescents do value their parents' input (Keller & Whiston, 2008; Lucas, 1997; O'Brien, Friedman, Tipton, & Linn, 2000). As noted by Keller and Whiston (2008), it is not necessarily explicit information (i.e., mechanical vs. biomedical vs. aerospace vs. mechanical engineering) that parents need but basic information to foster and support their adolescents' exploration of careers.

Of special concern from the current study is the limited knowledge of science and math teachers and counselors with respect to STEM careers, especially information technology and engineering. There is a need to meaningfully engage students in science, technology, engineering, and mathematics if the United States is to compete and lead in the 21st century. One barrier is the lack of well qualified teachers in these fields (Congressional Research Service, 2006; Paldy, 2005). Students' lack of interest in scientific careers may reflect the shortage of qualified teachers and poor facilities in many schools (Paldy, 2005). Finding effective ways to attract and retain well-qualified teachers in STEM fields is critical (Steinke & Putnam, 2007). Further, if teachers are not adequately prepared, they may use ineffective methods and techniques to teach dynamic subjects (Christie, 2008; Ritz, 2009; Wicklein, Smith, & Kim, 2009). How, when, and by whom students are offered opportunities to explore technology in secondary schools is an ongoing issue (Wicklein et al., 2009; Wright, Washer, Watkins, & Scott, 2008).

Counselors also hold key roles in encouraging students to consider career options. However, Smith (2009) notes that less than ten percent of school career advisors come from a science background and do not have the information or

expertise to adequately guide students into STEM opportunities. The lack of knowledge/expertise on the part of counselors in regard to STEM careers, coupled with limited expertise on the part of teachers, presents major problems in ensuring students are made aware of STEM career opportunities.

The lack of STEM education, opportunities, and career guidance is not only at the general educational level, but specifically a problem with underserved and underrepresented populations (Gilmer, 2007; Lam, Srivatsan, Doverspike, Vesalo, & Mawasha, 2005; Yelamarthi & Mawasha, 2008). Support through the educational system is especially important in encouraging young women and minorities (Kauffmann, Hall, Bosse, Batts, & Moses, 2009; Sullivan, Hall, Kauffmann, Batts, & Long, 2008). There has also been much debate concerning the commitment of higher education leaders to the achievement of diverse individuals in STEM careers (Hopewell, McNeely, Kuiler, & Hahm, 2009). Students, teachers, and leaders must understand that STEM fields are not only a pathway for understanding the world, but are also connected to social standing, economic prosperity, and healthier living. It is critical that people of diverse and underrepresented backgrounds get education, exposure, and career guidance in order to bridge the "STEM divide" which exists in relation and correlation to the well publicized digital divides within our society.

The results of the current study should be interpreted in light of certain limitations. The participant pool of high school students, parents, and teachers came from rural schools in the southeast, which may limit generalizability. The study, and grant, focused on high school students who had the ability to do well in the STEM fields, as indicated by their school records and teacher reports, but who may not have had opportunities to explore these fields due to limited school facilities, socioeconomic status, gender, and/or minority status. However, it should be noted that these underrepresented groups might well denote some of the best untapped resources across the US. We must attract far more students into these fields if we want to remain competitive in the world market.

Future research needs to focus on more rigorous experimental procedures in ascertaining the influence of parents and teachers on students' career considerations. In the current study, it was not possible to match parental response to the response from a high school student. It would be beneficial to assess parent and teacher knowledge and tie this directly to the interests/career options specific students indicate.

Given the findings of this study, STEM education programs and funding sources should consider more definite connections to secondary school career counseling and parental STEM education programs. Results of the current study found that roughly half of college students in engineering made that decision while still in high school, making this a critical time period. Teachers/counselors are individuals with whom students discuss their future plans and seek counsel. If school personnel have limited knowledge of these career options, many students may not know about or consider certain careers as viable choices.

Teachers are key players in encouraging student interest in various career options (Jackson & Nutini, 2002; Kenny, Blustein, Chaves, Grossman, & Gallagher, 2003; Lent et al., 2002; Paldy, 2005). Kenny et al. (2003) and Lent et al. (2002) further note that the importance of a career support system in the educational sector in mediating negative effects of barriers.

Additionally, parent groups should focus attention on helping parents understand their role in encouraging their sons/daughters to consider various career options. It is important that parents be given broad knowledge of career options. Parental attitudes play an important role in encouraging students to consider various career options, including career exploration, gender-typing, and future occupational plans (Turner & Lapan, 2005; Turner, Steward, & Lapan, 2004; Usinger, 2005).

Unless opportunities are provided to stimulate interest and encourage exploration of career options in STEM fields, engineering in particular, we will continue to have fewer students even consider these careers as options. As noted by Ritz (2009) exposure to educational experiences that promote analytical problem solving is beneficial to all students.

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This project was supported by NSF grant NSF 05-621. Any opinions, findings, and conclusions or recommendations expressed in this project are those of the authors and do not necessarily reflect the views of the National Science Foundation.