Investigating Student Interest in Post-Secondary STEM Education

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Introduction

In a world of rapidly changing technology, knowledge explosion, and globalization, there is a fundamental shift in the type of workforce America needs to remain competitive in a complex and integrated global market. Trends and projections of enrollment and degree production suggest a shortfall in scientific and technical capabilities. For example, from 1993 to 2000, the number of public high school graduates went up by 14.6%, but engineering degree production went down by 6.1%. This decline is particularly disturbing given the changing demographics of the US. American children are falling behind in STEM skills; they are simply not "world-class learners" in science and math. The Third International Mathematics and Science Study tested the students of 41 nations. Children from the U.S. were among the leaders in the fourth grade assessment, but by high school they were almost last[1]. Interest in scientific and mathematical ideas is declining, and students are not being instructed to a level of competence they will need to perform challenging jobs productively.

Another area of concern is the academic achievement of K-12 minority students. Despite the narrowing of achievement levels between white and minority students during the 1980s, particularly in math, recent data raise the possibility that the gap is no longer closing[2]. Social scientists attribute these differences to high levels of poverty in families of minority children and less education of their parents. It is difficult for schools to compensate for such disadvantages. However, there is evidence that extraordinary schools and teachers make a difference in how all students perform. Research on early intervention and one-on-one tutoring demonstrates that at-risk students can achieve at far higher levels than they have in the past[3,4]. There is also evidence that taking more challenging STEM courses is related to higher student performance[5,6]. Raising student achievement requires teachers to meet not only academic needs but also social and cultural needs of students[7]. This is particularly important because more students are Hispanic (17%) and African American (17%) than teachers (Hispanic: 5% and African American: 8%) in public schools[8].

The gap between girls' and boys' achievement and participation in science and math during secondary school education, though narrowing, still exists. In science, data showed no significant differences among 4th and 8th grade girls and boys, but 12th grade boys had higher scores than girls. A recent study of 14 School-to-Work sites found that more than 90% of the girls had traditional female jobs and "boys tended to dominate almost to the point of exclusion in many industrial and engineering programs"[9].

The most powerful instrument for change lies at the very core of education: teaching and learning. However, teacher training and professional development in science and math are inadequate to meet the needs of current students. Instructors in many STEM-related classes are poorly prepared. Over 12% of all new hires enter the classroom without any formal training in STEM skills[10]. Less than half of all math teachers in the US have a major or minor in math, and 28% of math teachers (18% of science teachers) lack state certification in the subjects they teach. Our inability to attract and keep good teachers grows. Over 30% of all new teachers leave within three years and there are higher rates among math and science teachers in high-poverty schools[11]. This shortage comes when expectations for what students should know in math and science are rising[12]. Recent research indicates "that measures of teaching preparation and certification are by far the strongest correlation of student achievement in reading and mathematics, both before and after controlling for poverty and language status"[13]. It appears that our current pedagogical style may focus on teaching methods that feel good, or are fun, instead of techniques that result in solid learning[14]. Teacher training is not simply a matter of preparation; it depends just as much on sustained, high-quality professional development.

To further understand the intricacies and implications of the issues presented above and their local manifestations, a team was formed of the faculty from the University of Cincinnati (UC) Colleges of Engineering and Education (IHE faculty); teachers of STEM courses from local high schools and their administrators (teachers and administrators); and professionals from the Cincinnati community (advisors) through a NSF Bridges to Engineering Education (BEE) planning grant. Seven focus group discussion meetings were conducted. Attendees included 39 administrators and teachers from 14 school districts in and around Cincinnati, and 11 professionals to formulate initiatives that will specifically prepare students to be successful in college and increase IHE enrollments in STEM disciplines. The meetings focused on causes of declining enrollment and underrepresented groups in STEM disciplines, particularly engineering, in IHE, and how to help alleviate these conditions. To gain a better grasp of the "reality on the ground" a survey was conducted in the spring of 2003 of among 4,263 students from 14 school districts. We also wanted to learn what influenced current UC's College of Engineering students' decision to study engineering and why at UC, and also obtain information related to retention. Surveys were given to all engineering majors, and 620 students from all classes (freshmen-seniors) responded.

The paper will first present the organization of the meetings with the teachers, administrators and advisors to seek the information desired. Second, the findings from these meetings and the need to conduct the student surveys will be presented. Third, the results of the two surveys will be presented and discussed, and the follow up meetings held with teachers and administrators to address the implications of findings from these surveys will be presented. Finally, in light of the results, opportunities for early interventions to enhance STEM learning across all levels were identified, which will be presented in a separate paper.

Data Gathering – Among K-12 Teachers, K-12 Administrators, and Advisors

Data gathering were organized as part of a one-year Bridges to Engineering Education (BEE) planning grant, Project SMART, in which seven focus group discussion meetings were conducted during the fall of 2002, and one final meeting in May 13, 2003.

As the role of technology continues to grow in society, K-16 educators need to integrate STEM skills throughout curricula to adequately prepare students for life long success. To address this national need, faculty from the UC Colleges of Engineering and Education (faculty); teachers of STEM courses from local high schools (teachers); administrators from local high schools (administrators); and a cross section of professionals from the Cincinnati community (advisors) formed an *ad hoc* project team. The following four objectives guided meetings of the *ad hoc* project team:

1. Determine what students, teachers, and school administrators know about engineers and the engineering profession.
2. Brainstorm to identify activities that could be undertaken to change the views students and teachers have of engineering.
3. Identify the most highly preferred activities and solicit buy-in from teachers and school administrators,
4. Solicit critical feedback from an advisory board of local professionals from the Cincinnati community.

Three types of meetings were conducted:

1. The faculty from the UC met as a group to develop agendas and review feedback from each meeting. The faculty meetings generally occurred on a bi-weekly or on an as-needed basis and involved approximately six individuals meeting for two hours during the business day.
2. The second type of meeting used faculty from the UC as scribes to record the focused discussions of the teachers and administrators from local high schools. These meetings were scheduled in advance, participants were provided with an agenda, the meetings took place in the evening for three hours, and 39 participants from local high schools from 14 school districts participated, and each received a stipend. In general, from each district a math or science secondary school teacher and an administrator were selected, based on the district Superintendent's recommendation.
3. The third type of meeting included faculty from the UC discussing the project with an advisory board of 14 local professionals from the greater Cincinnati area. These meetings were intended to present the input received from the teachers and administrators and to solicit feedback of a broad-scope, and were therefore conducted on a limited basis, in the evening for three hours.

Meetings involving teachers, administrators, or advisors included an initial presentation of the objectives of the meeting with clarification of common questions and followed with break-out group discussions of five to seven participants teamed with at least one faculty member from UC who acted as a scribe for each break-out group. After each meeting, an anonymous evaluation form was distributed and collected to determine participant satisfaction with the format, content, and outcome of the meeting.

As project action items were developed they were posted on the project Blackboard Site®, and input was sought from the teachers and administrators, who posted their comments. As this process was progressing, K-12 and UC engineering undergraduate student surveys were conducted in the spring of 2003, which are discussed in the following section. The surveys basically reconfirmed the input we had received earlier, but also shed light in understanding when and in what form intervention would be most effective as far as enhancing learning of math and science skills is concerned.

The preliminary survey results from the secondary schools, and also the district student performance statistics were shared with the teachers and administrators in advance and a meeting to discuss them was held on May 13, 2003. Six questions were used to guide the discussion:

1. What is your initial input regarding the survey results as were distributed? Is there anything particular about your school district that the survey reveals? How should the survey data be categorized and analyzed further in order to interpret the results in a meaningful manner?
2. What insights do you gain from the performance statistics of participating school districts?
3. What are your reactions to:
   3.1. Value and sustainability of the activities proposed?
   3.2. Concepts of Teacher-Leaders/Mentors as the driving program reform effort?
   3.3. Duration and nature of research experiences for teachers? Should a sabbatical program be included?
4. Do you know if your school district will be a partner in our Targeted MSP? Who should be contacted in your school district? Can you help?
5. How can we continue to share our ideas and receive feedback from you?
6. Are there specific issues that should be addressed?

For each question, a brief presentation was provided, a discussion pursued, and finally the teachers and administrators were asked to provide a written response to each question. They were pre-informed about the format of the meeting. Table 1 (see next page) summarizes these meetings and the outcomes of each successive meeting. It should be noted that the meetings were so organized that the results of one were used to build on the next one, with the ultimate objective to identify what actions need to be taken in order to solve the problem at hand: how to enhance interest in STEM education among K-12 students.

Data Gathering – Among K-12 Students

A K-12 survey was developed at the University of Cincinnati to gather information directly from students to verify the teachers' statements regarding K-12 students' perceptions of the engineering profession and studying engineering in college. This survey was distributed via e-mail, on March 7, 2003, to all teachers and administrators involved in the data collection focus groups.

Table 1. Summary of BEE Meetings

Meeting Date	Participants	Objectives	Outcomes
1	Faculty	• Set the agenda for Meetings 2 and 3.	• Selected three questions to guide breakout group discussions.
2 10/22/02	Teachers & Administrators & Faculty	• Present an overview of the MSP program and preliminary ideas for a targeted MSP proposal. • Ask, "Why is engineering enrollment declining?" • Ask, "What can be done to reverse this trend?" • Ask, "What do students think an engineer does?"	• Math and science cause fear of students to select alternatives. • Students need personal contact with engineers as role models. • Engineers are "nerds" with pocket protectors and calculators.
3 10/29/02	Advisors & Faculty	• Same as Meeting No. 2.	• Discussion focused upon MSP proposals being developed by other agencies in Ohio.
4	Faculty	• Summarize discussions from Meetings 2 and 3. • Set the agenda for Meetings 5 and 6.	• Surprised by the negative perception of engineers and engineering. • Identified six points for clarification and selected three questions to guide breakout group discussions.
5 10/30/02	Teachers & Faculty	• Ask, "How do we prepare students for college?" • Ask, "How do we provide facts about engineering?" • Ask, "How can we modify student perception?"	• Get involved in setting State math and science standards and preparing teaching materials. • Facilitate personal contact among engineers, students, and teachers. • Develop positive role models.
6 11/6/02	Administrators & Faculty	• Same as Meeting No. 5.	• Integrate engineering with ongoing activities – resources are already stretched too thin. • Emphasize centers of learning.
7	Faculty	• Summarize discussions from Meetings 5 and 6. • Set the agenda for Meeting 8.	• Developed MSP proposal v 1 including five broad target areas.
8 11/19/02	Teachers & Faculty	• Ask, "What are the pro's, con's, and alternatives?" • Ask, "What is relative value of each proposed activity?"	• Teachers "voted" to identify the most important proposed activities.
9	Faculty	• Evaluate the response from Mtg 8.	• Developed MSP proposal v 2.
10 12/4/02	Teachers & Administrators & Faculty	• Solicit "buy-in."	• Modified the proposal to emphasize teacher professional development.
11 12/12/02	Advisors & Faculty	• Solicit "buy-in."	• Need direct student input. • Need to focus upon sustainability and how to integrate with ongoing education system. • Need to include underrepresented groups.
12	Faculty	• Format for the secondary student and university student surveys. • Identify responsibilities for further proposal development.	• Assigned action items to individuals for student surveys. • Assigned action items to individuals for proposal development.

The University team did not give teachers specific directions related to survey distribution. We asked for their "assistance in collecting this data, … it would be helpful to us if you let us know answers to these questions from students in your school." (Kukreti e-mail message dated 3/7/2003). The teachers and administrators collected this data because they felt it would be useful. These general directions for survey distribution lead to each school district collecting data differently. Overall distribution observations include:

1. The surveys were distributed to students in grades 6 through 12, but not all grade bands are represented in all school districts.
2. Hamilton City school district distributed the surveys to all students in 10^{th}, 11^{th} and 12^{th} grade. These results are probably typical of the school district.
3. Fairfield school district distributed their surveys to all science students in grades 10^{th}-12^{th} with some additional surveys from college pre and accelerated math class (classes taught by the Mathematics teacher involved in the project). This sample is probably typical of students in the districts since most students need to take a science course in sophomore, junior or senior year in high school.
4. The other school districts used convenience samples. Some are more typical of the school district than others. For example, Cincinnati City's results are most likely not typical of the school district in general, but Fairfield may be fairly typical since all students in science classes were surveyed.
5. Lakota school district's results are probably typical of 6^{th} and 7^{th} graders in the district since many students were tested and the classes surveyed were typical for the intermediate school.
6. Very few school districts surveyed 6^{th}-8^{th} graders. The teachers involved were primarily high school teachers and the samples were convenience samples, not random or experimental.

The number of students who responded to the surveys from each school district, their grade levels, gender distribution, and race/ethnicity variation are presented in Figures 1 to 4, respectively.

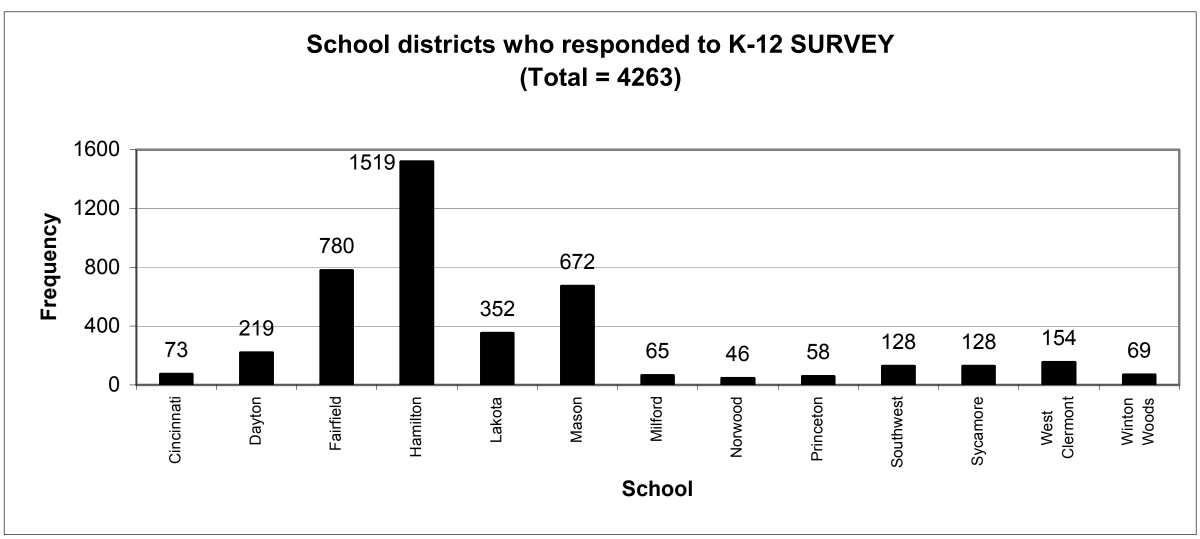

Figure 1. School Districts: Number of Students Who Responded to the K-12 Survey

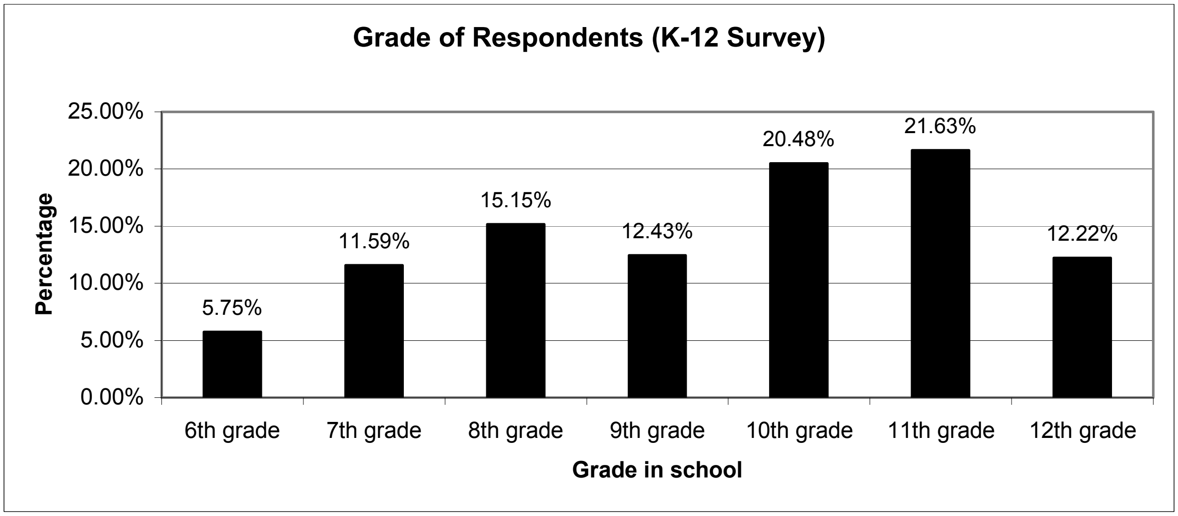

Figure 2. Grade Levels: Of the Students Who Responded to the K-12 Survey

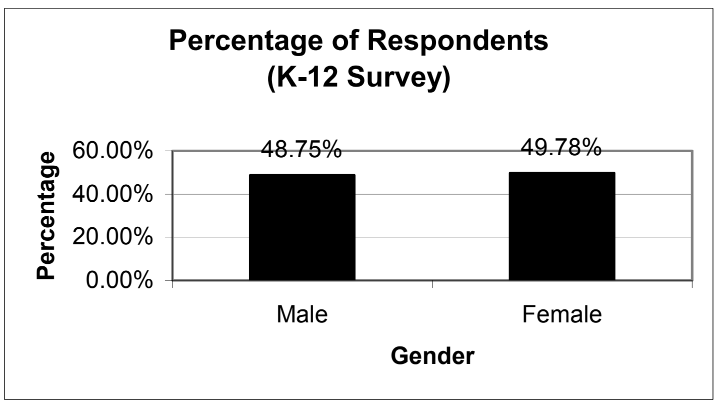

Figure 3. Gender Distribution: Of the Students Who Responded to the K-12 Survey

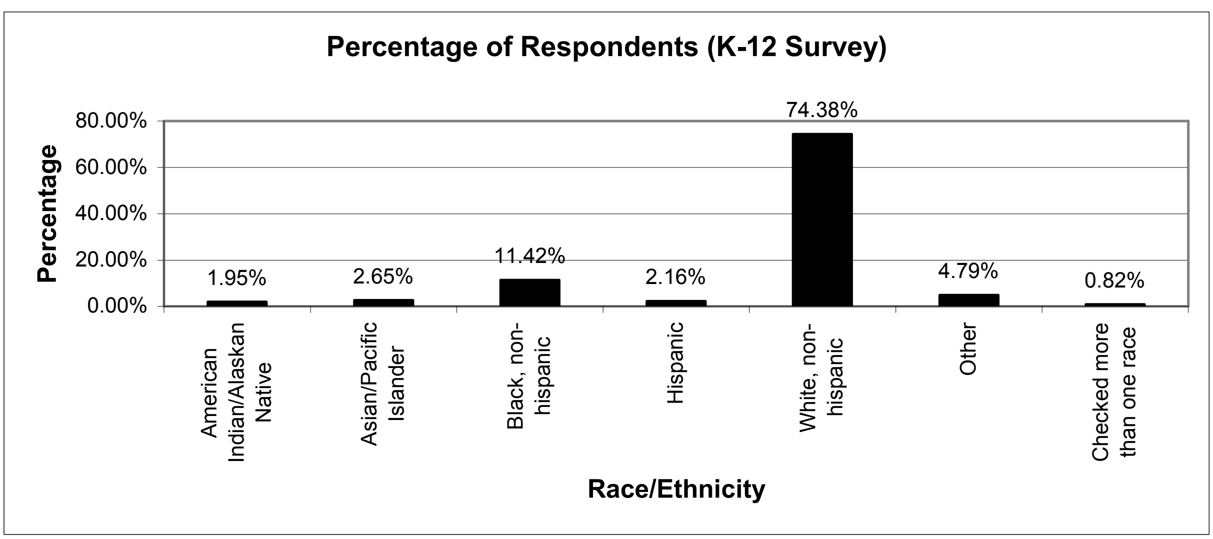

Figure 4. Race/Ethnicity Variation: Of the Students Who Responded to the K-12 Survey

The K-12 Survey results were summarized in two major points:

1. Overall, our sample size combines data from 13 school districts. The results indicate that interest in engineering varies slightly by grade peaking in 9th-10th grades (29.8% interest in being an engineer).
2. As data collection methods used within each district varied greatly, these overall results are a collection of students from varying backgrounds and math/science ability levels. The range of interest in engineering is almost always 20% or more for 11th-12th graders, in general. If the students are taking higher-level math or science classes, this percentage is over 30%.

Overall, almost 30% of the students who responded to the survey indicated that they would consider Engineering as a career choice. For 6th through 8th grade, the percentage is 28.84%. This percentage peaks at 29.79% for 9th-10th graders and then decreases to 27.27% for 11th-12th graders. This represents the "future possibilites" for College of Engineering applications but only 5% of high school graduates apply as freshmen nationwide. Why is there such a discrepency? Can we find a way to bridge this gap?

To help anwer these questions, we looked at the written responses given to explain why students chose either YES or NO. The responses were grouped into following six clusters:

1. Like creating, designing, constructing , problem solving and hands on experiences
2. Likes math and science and other areas that prepare for the field of engineering
3. Had prior exposure or contact, knowledge of engineering, benefits of the profession, etc., which is impacted the decision to go to engineering
4. Considers it a rewarding profession, appealing profession, one that leads to satisfaction, and opportunities to help the society
5. Lack of knowledge, negative impressions of self capabilities, no desire to pursue prerequisite coursework, and dislike for the engineering profession
6. Response leads to no conclusion.

Table 2 summarizes the repsonses obtained from the students in response to these six clusters. The POSITIVE (i.e., YES) and NEGATIVE (i.e., NO) repsonse were further scrutinized by gender distribution, minority status and by grade levels. For each the responses obtained form the urban and suburban schools districts were looked at separately, since the minority status of these school districts varied significantly. The results for each of these cases are presented in Tables 3 to 8, respectively.

If there was a POSITIVE response, response 1 (like doing what engineers do) was the most given response category, as can be seen in Table 2. Looking at gender differences, of the students in this category, there were more males than females, as can be seen in Table 3. Of respondents giving response 2 (like math and science), the levels were higher for suburban versus urban students and females versus males. More urban students responded that engineering was a rewarding profession (response 4). Prior experiences with engineers were stated by ~ 20% of the respondents equally, as cane be seen in Table 7. These differences between males and females become more pronounced as the students get older. By 11th and 12th

Table 2. "Why Or Why Not Are You Interested In Being An Engineer?" - All Students

RESPONSE CATEGORY	YES (n=1673)		NO (n=3434)	
	#	%	#	%
• Like creating, designing, constructing, problem solving, and hands-on experiences	530	31.7	17	.5
• Likes math and science and other areas that prepare for the field of engineering	335	20.0	14	.4
• Had prior exposure or contact, knowledge of engineering, benefits of the profession, etc., which is impacted the decision to go to engineering	347	20.7	37	1.1
• Considers it a rewarding profession, appealing profession, one that leads to satisfaction, and opportunities to help the society	287	17.2	12	.3
• Lack of knowledge, negative impressions of self capabilities, no desire to pursue prerequisite coursework, and dislike for the engineering profession	53	3.2	3064	89.2
• Response leads to no conclusion	121	7.2	290	8.4

Table 3. "Why (YES) Are You Interested In Being An Engineer?" – By Gender

RESPONSE CATEGORY	Urban (n=694)		Suburban (n=966)	
	Males (n=532) %	Females (n=162) %	Males (n=753) %	Females (n=213) %
• Like creating, designing, constructing, problem solving, and hands-on experiences	36.8	33.3	30.8	21.1
• Likes math and science and other areas that prepare for the field of engineering	11.7	15.4	22.6	34.7
• Had prior exposure or contact, knowledge of engineering, benefits of the profession, etc., which is impacted the decision to go to engineering	21.6	19.8	20.8	19.7
• Considers it a rewarding profession, appealing profession, one that leads to satisfaction, and opportunities to help the society	17.3	20.4	16.6	16.9
• Lack of knowledge, negative impressions of self capabilities, no desire to pursue prerequisite coursework, and dislike for the engineering profession	2.3	1.9	3.7	3.8
• Response leads to no conclusion	10.3	9.3	5.4	3.8

Table 4. "Why (NO) Aren't You Interested In Being An Engineer?" – By Gender

RESPONSE CATEGORY	Urban (n=1398)		Suburban (n=1994)	
	Males (n=491) %	Females (n=907) %	Males (n=702) %	Females (n=1292) %
• Like creating, designing, constructing, problem solving, and hands-on experiences	0.2	0.6	1.0	0.3
• Likes math and science and other areas that prepare for the field of engineering	0.8	0.1	1.0	0.2
• Had prior exposure or contact, knowledge of engineering, benefits of the profession, etc., which is impacted the decision to go to engineering	0.4	0.3	1.7	1.5
• Considers it a rewarding profession, appealing profession, one that leads to satisfaction, and opportunities to help the society	0.6	0.2	0.9	0.0
• Lack of knowledge, negative impressions of self capabilities, no desire to pursue prerequisite coursework, and dislike for the engineering profession	83.1	90.8	84.6	93.2
• Response leads to no conclusion	14.9	7.9	10.8	4.8

Table 5. "Why (YES) Are You Interested In Being An Engineer?" – By Minority Status

RESPONSE CATEGORY	Urban (n=700)		Suburban (n=973)	
	Minority (n=203) %	Non-min. (n=497) %	Minority (n=83) %	Non-min. (n=890) %
• Like creating, designing, constructing, problem solving, and hands-on experiences	30.0	38.4	20.5	29.3
• Likes math and science and other areas that prepare for the field of engineering	15.3	11.5	20.5	25.8
• Had prior exposure or contact, knowledge of engineering, benefits of the profession, etc., which is impacted the decision to go to engineering	23.2	20.3	27.7	19.8
• Considers it a rewarding profession, appealing profession, one that leads to satisfaction, and opportunities to help the society	15.8	18.7	22.9	16.1
• Lack of knowledge, negative impressions of self capabilities, no desire to pursue prerequisite coursework, and dislike for the engineering profession	2.0	2.2	2.4	4.0
• Response leads to no conclusion	13.8	8.9	6.0	4.9

Table 6. "Why (NO) Aren't You Interested In Being An Engineer?" – By Minority Status

RESPONSE CATEGORY	Urban (n=1422)		Suburban (n=2012)	
	Minority (n=295) %	Non-min. (n=1127) %	Minority (n=183) %	Non-min. (n=1829) %
• Like creating, designing, constructing, problem solving, and hands-on experiences	0.0	0.5	1.1	0.5
• Likes math and science and other areas that prepare for the field of engineering	0.3	0.4	0.0	0.5
• Had prior exposure or contact, knowledge of engineering, benefits of the profession, etc., which is impacted the decision to go to engineering	0.0	0.4	2.7	1.5
• Considers it a rewarding profession, appealing profession, one that leads to satisfaction, and opportunities to help the society	0.3	0.4	1.1	0.3
• Lack of knowledge, negative impressions of self capabilities, no desire to pursue prerequisite coursework, and dislike for the engineering profession	84.1	89.3	89.1	90.0
• Response leads to no conclusion	15.3	9.1	6.0	7.2

Table 7. "Why (YES) Are You Interested In Being An Engineer?" – By Grade

RESPONSE CATEGORY	Grade 6-8 (n=409)		Grade 9-10 (n=411)		Grade 11-12 (n=414)	
	Male n=323 %	Female n=86 %	Male n=327 %	Female n=84 %	Male n=328 %	Female n=86 %
Like creating, designing, constructing, problem solving, and hands-on experiences	42.7	30.2	28.4	23.8	24.1	15.1
Likes math and science and other areas that prepare for the field of engineering	10.5	14.0	17.4	29.8	22.6	37.2
Had prior exposure or contact, knowledge of engineering, benefits of the profession, etc., which is impacted the decision to go to engineering	18.0	19.8	21.1	14.3	20.4	19.8
Considers it a rewarding profession, appealing profession, one that leads to satisfaction, and opportunities to help the society	15.2	23.3	20.5	22.6	19.5	20.9
Lack of knowledge, negative impressions of self capabilities, no desire to pursue prerequisite coursework, and dislike for the engineering profession	5.0	3.5	3.1	2.4	3.4	1.2
Response leads to no conclusion	8.7	9.3	9.5	7.1	10.1	5.8

Table 8. "Why (NO) Aren't You Interested In Being An Engineer?" – By Grade

RESPONSE CATEGORY	Grade 6-8 (n=945)		Grade 9-10 (n=952)		Grade 11-12 (n=1007)	
	Male n=364 %	Female n=581 %	Male n=364 %	Female n=588 %	Male n=372 %	Female n=635 %
Like creating, designing, constructing, problem solving, and hands-on experiences	1.1	0.7	0.3	0.2	0.3	0.2
Likes math and science and other areas that prepare for the field of engineering	0.5	0.2	0.8	0.0	0.8	0.3
Had prior exposure or contact, knowledge of engineering, benefits of the profession, etc., which is impacted the decision to go to engineering	1.9	1.4	0.8	0.9	1.1	1.3
Considers it a rewarding profession, appealing profession, one that leads to satisfaction, and opportunities to help the society	0.5	0.2	0.8	0.0	0.5	0.2
Lack of knowledge, negative impressions of self capabilities, no desire to pursue prerequisite coursework, and dislike for the engineering profession	83.8	89.2	80.5	92.0	86.6	92.6
Response leads to no conclusion	12.1	8.4	16.8	7.0	10.8	5.5

grades, 37% of females stated that they would be interested in being an enginner because they liked math and science. Responses by males were more evenly distributed between responses 1-4. Differences between minority and non-minority students seem to follow the trends similar to the males, as can be seen in Tables 5 and 6. If there was a NEGATIVE response, the overwhelming reason was "Lack of knowledge, negative impressions of self capabilities, no desire to pursue prerequisite coursework, and dislike for the engineering profession", response 5.

In general, K-12 students do have an limited idea of what engineers do when they are directly asked via a list of skills. The area for opportunity in correcting misconceptions is in student perceptions of enginnering skills used in the workplace. In the lower grade, students mix engineers with technicians (repair, drive trains …). In the middle grades, students list tasks ("drafting, building, problem solving …). In upper grades, students list skills needed (science, math, design, computer and visual aid …). These changing perceptions are problematic because in the lower grades, students do not see the connection of science and math to engineering and do not develop these skills. In the middle grade, students find math and science difficult and stop taking these classes. In the upper grades, they desire to be an engineer but see it as an impossible task. These perceptions were reinforced when the students were asked to describe engineering students. While the answers were diverse, they seperated into too broad categories, the study of engineering and personality. Comments related to the study of engineering included: "curriculum is hard", "too many math classes", "always glued to computers", "very structured – no room to accommodate other interests". Comments related to personality included: "smart but nerd", "introverts", "do not have opportunities to enjoy life".

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These misconceptions and lack of skills can be mediated with increased exposure to positive engineer role-models, programs to increase math and science skills, and more positive public relations for College of Engineering curriculum. These ideas will be discussed in more details later in this report.

Data Gathering – Among College Students

Data were collected from 620 current University of Cincinnati College of Engineering undergraduate students during the spring quarter 2003. The purpose of this survey was to determine what or who influenced student's decision to study engineering and to study at UC. Respondents also identified whether or not certain skills were needed for an engineer to do their job and their demographics. All engineering majors and graduation years were represented in this sample. Additionally, the sample was representative in relation to gender (15% females) and ethnicity (15.81% minorities). Faculty members distributed these surveys during regularly scheduled classes.

A summary of College Survey results can also be summarized in two major points:

1. College students were able to successful identify skills needed by engineers to do their jobs. These results are presented in Figure 5. The skills listed were taken from an industry-recognized survey of professional engineers. They included problem solving, technical skills, oral communications skills, written communication skills, math/science proficiency, ethics and professionalism, computer skills, desire for lifelong learning, business management practices, and global outlook. As can be seen from Figure 5 (see next page), of the skills listed, college students were least likely to identify the final three skills as skills used by an engineer when they work (77.4%, 63.23% and 7.74%, respectively).
2. UC students indicated "always wanting to be an engineer" or "positive familiarity with an engineer" as their most frequently listed college choice influences. These results are presented in Figure 6 (see next page). As can be seen from this figure, their main reasons

for coming to UC were its co-op program, location, cost, and reputation. (The College of Engineering at UC introduced co-op engineering education in 1906, and has maintained a mandatory cooperative system ever since. Our undergraduate degree programs span five academic years and include an average of six co-op quarters.) These responses from college students reiterated the importance of positively portraying careers in engineering and giving students' positive role models in the early and middle grades.

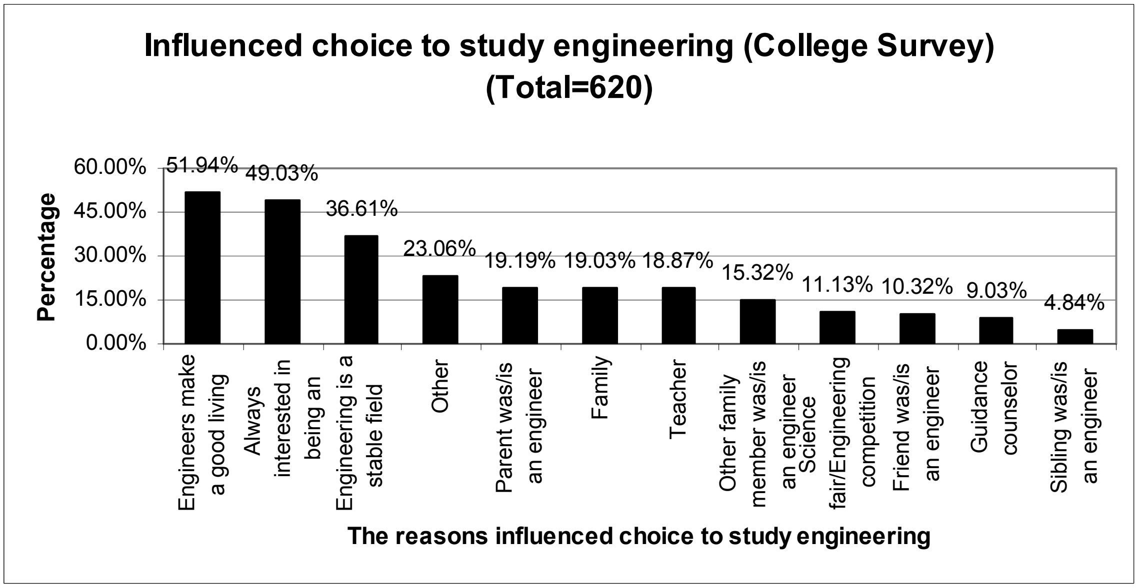

Figure 5. Influences to Study Engineering in College

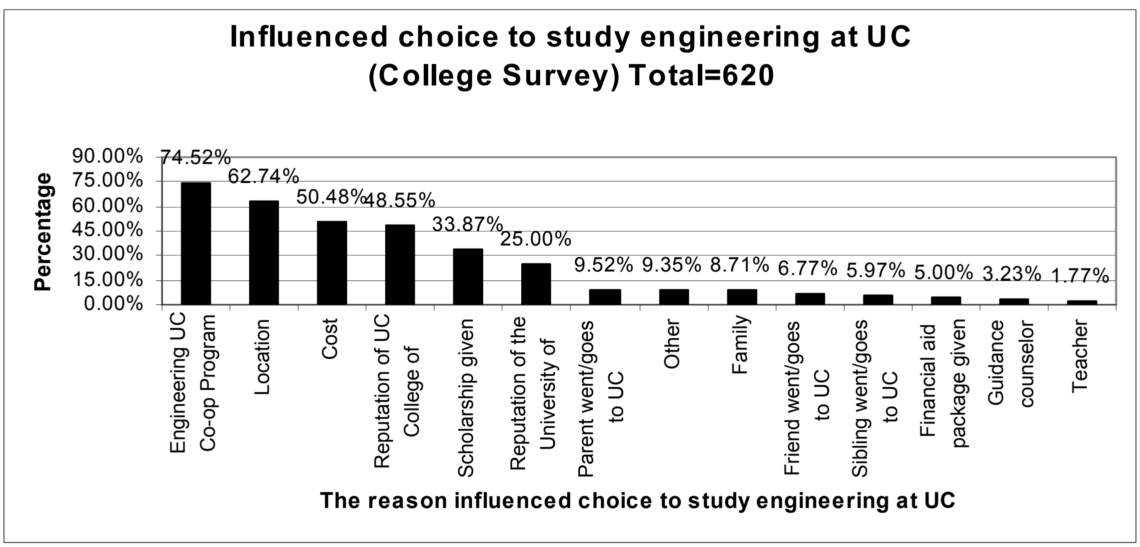

Figure 6. Reasons That Influenced Decision to Study Engineering at UC

Conclusions

The K-12 student survey respondents indicated that about 28% of the 6-12 graders are interested in engineering. Yet only about 5% of high school graduates apply for engineering admission. Our survey suggests that during grades 6 through 8 students' perceptions of what engineers do is not accurate. They tend to confuse engineers with technicians, rather than problem solvers. It could be due in part to this lack of understanding that they do not realize what math and science skills are needed to study engineering. Students in 9th and 10th grade start developing a better understanding of what engineers do (e.g., design, test, analyze, solve complex problems) and that they need to have good math and science skills. Due to weaknesses in their prior skills in these areas, however, many feel that math and science classes are too demanding. Thus, if we can motivate students in grades 6 through 8 to develop an active interest in math and science and then to concentrate on "skill building" in grades 9 and 10, we will have a larger pool of candidates that may consider engineering as a career choice. Then in grades 11 and12 we can offer programs to maintain math and science skills that also introduce pre-engineering and technology (computers, multi-media simulations, sensors, automated data acquisition systems, etc.) so that the students are better prepared to study engineering or other STEM education in college.

The College student survey results indicate that students wanted to be an engineer because it was a stable living and they always had an interest in engineering. These students identify University of Cincinnati's Co-op program (which is ranked in the top ten nationally by the U.S. News & World Report), location, cost and the reputation of the College of Engineering as top reasons for studying at UC.

The project ideas and partnership with the K-12 teachers and administrators and the professionals from the local community that resulted from the BEE planning grant helped develop a model for sustainable improvement on math and science learning with an engineering context. This model will be presented in a separate paper. This model includes opportunities for early interventions to enhance STEM learning across all levels. It includes opportunities to (a) capture the MTV generation's interest and imagination by creating a learner-centered STEM environment; (b) provide early intervention in requisite STEM skills; (c) develop a sustained partnership among IHE faculty and K-12 teachers; and (d) provide high quality professional development for in-service and pre-service teachers.

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