Mathematically Defining the Nature of an Engineer

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Abstract

Engineering education is more than just taking and passing the right courses—it is an integration of interest in things and ideas, a strong interest in learning by doing and seeing, and problem solving often with limited data. Engineers are different from other people in society both in their nature, responsibility, and rewards for work. Currently, society needs more engineers.

Generally, when society increases demand for engineers and increases the recruiting of engineers, retention percentages decrease and the cost to generate an engineering graduate increases. The College of Engineering at Texas Tech University is working on a solution to this problem. Part of the solution is to define the nature of engineers and to develop a cost-effective way to assess and sort students into their "best-fit" career choice early in their education.

This paper reports the results of a survey that attempts to mathematically define the nature of various college majors including engineering. A discussion of how this information can be used to select a college major is provided. The final delivery of this process will be a web-based tool that is easy to use. A discussion and demonstration of an existing preliminary tool will be included in the presentation.

Introduction

There is a shortage of engineering, math, and science professionals. Thus, there is a need to recruit more people to major in engineering. On the other hand, a high percentage of students who start as engineering majors change majors or fail to succeed in their study of engineering courses during their first year in college. Thus, the graduation rate is relatively low. Why? Is it possible that we have recruited the wrong type of student? Are we using the wrong teaching methodology to accommodate the nature of engineers? Either of these questions implies a lack of understanding of the nature of engineers. A need, thus, exists to better understand and define the nature of engineers, especially if this understanding can be used to increase recruitment and retention.

The objective of this paper is to mathematically define the nature of engineers and to compare the nature of engineers to the nature of other professionals. Ben Franklin in *Poor Richard's Almanac*[1] stated "What value is there in knowing the names of things if you know not the nature of things." We identify people as engineers when they complete a degree in engineering. We define them as professional engineers if they practice engineering under the supervision of engineers and satisfy a state board with reference materials and usually the passage of an exam. Engineers work with things and ideas in design, testing, and production and generally like to learn by doing and visually analyzing the material. Engineers may be male or female but generally are male compared to nursing, which is generally a female profession. By providing mathematical measurements of the characteristics of engineers and other professions, we will be able to explain why some professions are predominately one gender and better understand recruitment and retention of students.

Development

The basis for our analysis is the partitioning of the brain for various functions. The left and right front lobes of the brain are used in analysis and creative thought. How we use these lobes affects our decision making process and our preference to study or work with things or people and data or ideas. Ideas tend to be processed on the right side of the front lobes of the brain, while data tends to be associated with the left side. Emotions and interest in people tends to be a right brain function and the study and preference to work with things is a left-side function. Occupations or areas of career interest can be mapped based on interest in data vs. idea and things vs. people [2,3]. A detailed discussion of these career-mapping relationships is provided by Harris-Bowlsbey, et al.[4]. This process is also related to the Meyers Briggs Type Indicator, MBTI. Gregory and Bagert [5] reported the development of a website http://edtool.coe.ttu.edu/eddoc that quickly facilitates a career analysis based on left- and right-brain functions of the front lobes of the brain. The career-mapping tool has become a popular and useful tool for helping students to succeed in college. The coordinates used to define the location on the career map provide a mathematical description of career interest. Engineers, for example, have a common location on the career map.

Most of the literature on career analysis does not make a distinction on brain function: front lobes vs. sensory input. Therefore, there is a tendency to overlook the sensory input information associated with career types. Obviously, the sensory input is critical for learning. A more complete mathematical description of a person occurs if a learning style analysis is added to the information from the career map. Gregory and Carter [6] defined a learning style based on partitioning of sensory information in the brain. This process defines a learning style spectrum with four numbers, one for each of the following: hearing, reading, somatic, and visual. This tool is also available at the website described above.

Both the career map and the learning style analysis have been used for over two years as a hand process followed by a web-based process. While data related to the career-mapping process can be found in the literature, the learning style data described above associated with career types is not available. Therefore, a survey was designed to obtain both career map and learning style data associated with majors in college. The survey consisted of having seniors in a desired major provide the input needed to develop a career map and to perform the learning style analysis. The survey process was submitted to the human subjects committee at Texas Tech University for review and to obtain permission to survey human subjects. No names were needed—just major. During 2001, 10 to 30 students per major in the most used majors were asked to complete the survey. A second survey to obtain data for missing majors will be completed in 2002. Results from the current work are given in the next session. The purpose of the survey was to obtain mathematical descriptions of majors. By using seniors, it was assumed that the data would also represent career types associated with major. Eventually, the website will be reprogrammed with a more complete algorithm to help students select careers and majors that fit their natural interest and learning style.

The survey form was designed to fit on one sheet. Career mapping is on the front page and learning style assessment is on the back. Background information was also collected. A copy of the form is attached in the Appendix.

Results

A summary of results to date is given in Table 1. Because hearing and reading are both language components, a language index was created by adding the hearing and reading values. The value of this index will be illustrated later. Majors within the College of Engineering had similar values as illustrated in Table 2. Majors within the Animal Science and Natural Resources College also had similar values and were combined into one major we named agriculture. There was one exception in agriculture--food technology. While the food technology had similar values for career map coordinates and learning style distribution, this major was unusual in that it had a high percentage of female students.

Majors in engineering including computer science had similar values, especially for the career map data. Because of these similarities, it is impossible to sort majors within engineering by either career map coordinates or by learning style preference. This task is achieved with a different process described by Gregory and Heinze[7], in a separate paper also included in the proceedings of this meeting. The gender effect associated with things/people value shown in this table will be discussed later in this paper.

Career Map Comparisons

A graphical comparison of the career map coordinates from Table 1 is shown in Figure 1. The things/people coordinate was used to determine the order in this figure. It should be noted that majors in business, such as business computer, financial transactions, and management have not completed the survey in sufficient numbers to be included in these results. These majors should have a strong data component and should be located between agriculture and law in this figure.

Table 1. Summary of career map and learning styles assessment by major.

Major	Career Map			Learning Style					Language
	Things/ people	Data/ ideas		Hearing	Reading	Somatic	Visual		Index
Engineering	0.2	0.2		21	37	70	72		58
Agriculture	0.0	0.1		31	31	64	74		62
Architecture	-0.1	0.5		34	36	66	64		70
Physical therapy	-0.3	-0.3		9	43	68	80		52
Law	-0.3	0.0		37	47	52	63		85
English	-0.5	0.1		46	54	35	64		100
Human Science	-0.6	0.1		38	30	55	77		68
Nursing	-0.6	0.0		31	35	60	73		67
Psychology & ESS	-0.7	0.0		45	34	53	68		79
Occupational therapy	-0.7	-0.1		30	39	59	72		69

Table 2. Comparison of results for majors within the College of Engineering.

Major	Career Map			Learning Style			
	Things/ people	Data/ ideas		Hearing	Reading	Somatic	Visual
Civil Engineering	0.2	0.3		30	25	68	76
Chemical Engineering	0.2	0.2		13	40	74	74
Environmental engineering	0.2	0.4		23	33	65	78
Computer Science	0.2	0.1		21	39	75	66
Construction Technology	0.3	0.2		22	37	66	76
Electronic Technology	0.4	0.0		18	47	73	62
Engineering Average	0.2	0.2		21	37	70	72
Standard Deviation	0.10	0.15		5.8	6.9	4.4	6.6
Male	0.3	0.2		24	35	69	72
Female	-0.1	0.2		16	35	76	73

No statistical analysis was performed on the data other than determining means and standard deviations. There is little or no value in knowing if a significant difference exists. The value occurs by knowing how close an individual location is to the mean location of a major. The order of best fit occurs by comparing the individual values of things/people and data/ideas. For example, a student with a (-0.6,0) location would fit any of the majors on the right side of Figure 1. There would be a low probability of enjoyment, however in engineering on the opposite end. Obviously, more information is needed to help the student with a coordinate of (-0.6,0) to find his or her most enjoyable major.

Because the brain function and process associated with determining career map locations and MBTI are similar, all of these processes have similar limitations. Thus, while the current career map process provided at our website is quick and easy to use and provides results that are easy to understand, the current process has the same weakness as MBTI, Discover, and other similar processes in terms of providing precise career information.

The learning styles analysis does, in fact, as suspected, provide a second independent variable to narrow the career options that fit an individual's interest. The results of the learning style analysis for the same majors are shown in Figure 2. Note that the learning style pattern was used to reorder the majors. The English major is now on the left with a relative uniform interest in learning by all components of sensory input partitioned in the brain. This major has relatively high interest in learning using language components of hearing and reading. On the opposite end, physical therapy majors have very specific interest in learning by holistic vision and somatic or hands-on processing. They have almost no interest in learning by hearing and probably are at risk of low academic performance in history or political science classes taught only with verbal information. History for engineering majors (similar learning style pattern) is the third most problematic course after calculus and chemistry for freshmen. The ordering of majors in Figure 2 appears to be independent of the order of majors in Figure 1.

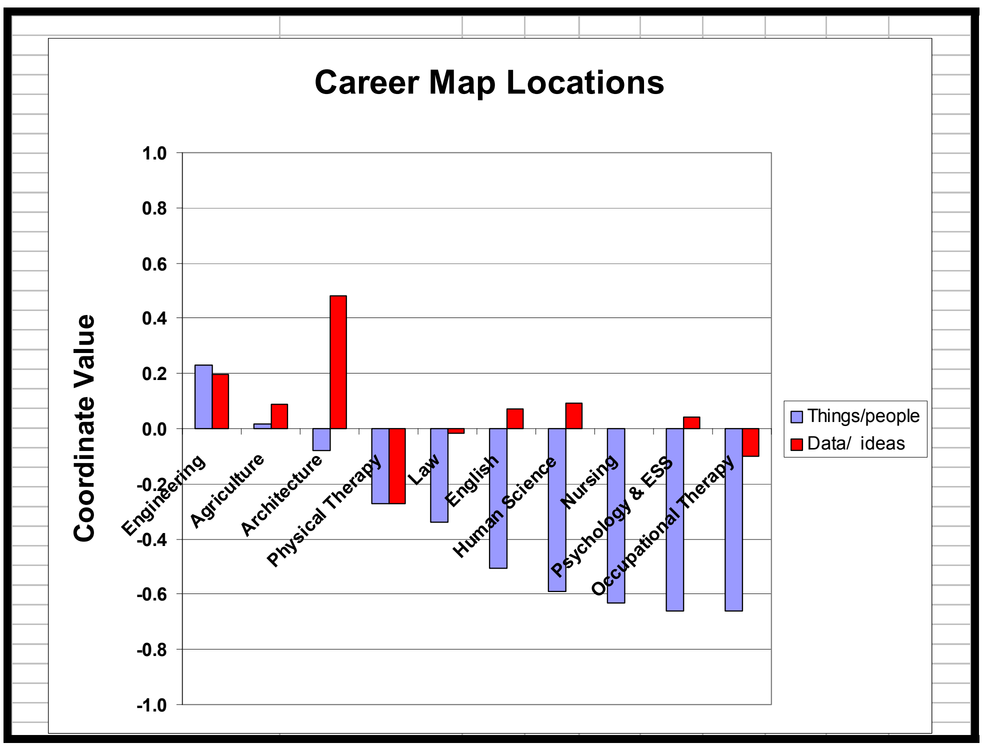

Figure 1. Variations in career map coordinate values as a function of major.

The independence of the learning style variable and the career map variable were checked by calculating the sum of the squared differences between the average career coordinate for engineering and the career coordinate for other majors and regressing this sum of squares to that obtained for the same process with learning styles. This analysis was done for all individual majors instead of the shortlist of grouped majors in Table 1. The final R^2 value between the two lists of sum of squares was very near zero indicating no correlation between the two variables. In other words, the career map and learning style variables are independent.

While the learning style spectrum shown in Figure 2 reveals differences between majors, it is complicated for individual comparison without the use of a computer for calculations. The language index reported in Table 1 can help with this comparison.

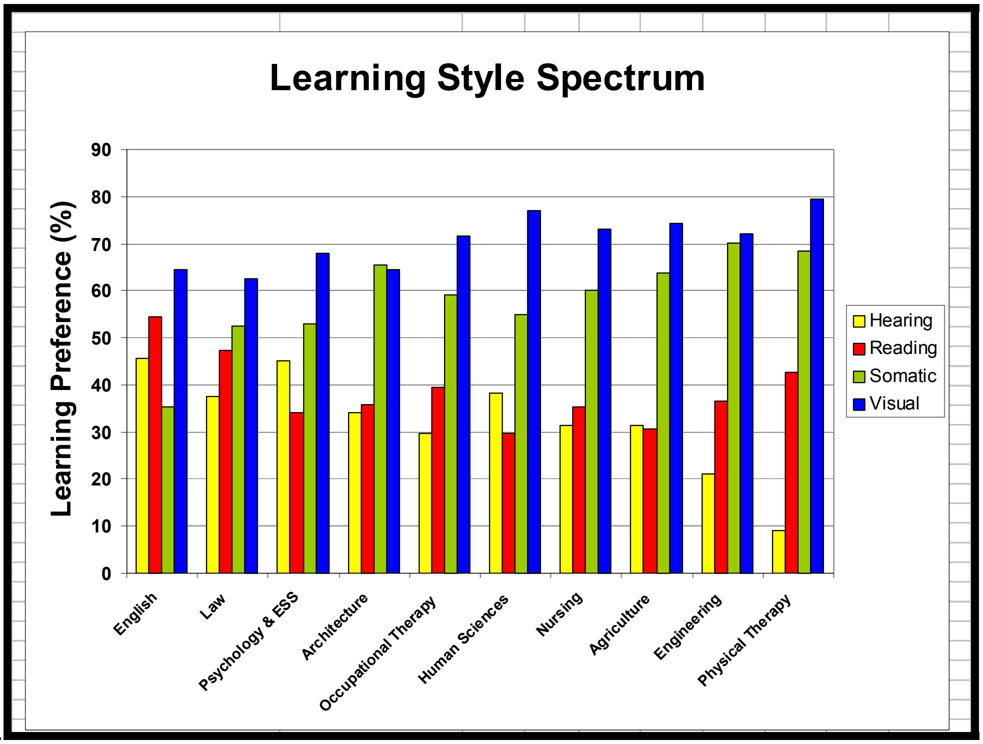

Figure 2. Variation in learning style spectrum for different majors.

The language index association with major is shown in Figure 3. It is logical that English, law, and psychology are majors with high language skills. It is just as logical that agriculture, engineering, and physical therapy, and probably most science majors are hands-on and visual learners. These differences have value for success in each major and also can be used to help students to select an appropriate career.

Gender Effects

As mentioned earlier, some majors, such as nursing and physical therapy tend to attract female students while other majors, like engineering, attract male students. Felder et al.[8] recently reported a difference in academic success associated with MBTI and gender: "The implication is that women with a preference for feeling on the MBTI may be particularly vulnerable in engineering school,…" Felder et al. reported that women tended to exit engineering or at least chemical engineering for both academic and non-academic reasons. It is obvious that women generally do not choose engineering as a major with the same interest as men.

The results from this survey help explain these observed gender differences. First, it should be noted that the people interest (negative value for things/people variable) and the feeling variable in MBTI are closely related. One problem with the MBTI for career analysis is that thinking or feeling are types of personality classifications. The process types a person into either thinking or feeling. There is no degree of interest in thinking or things compared to feeling or people. The MBTI is, thus, not a precise tool to determine career interest or degree of career interest.

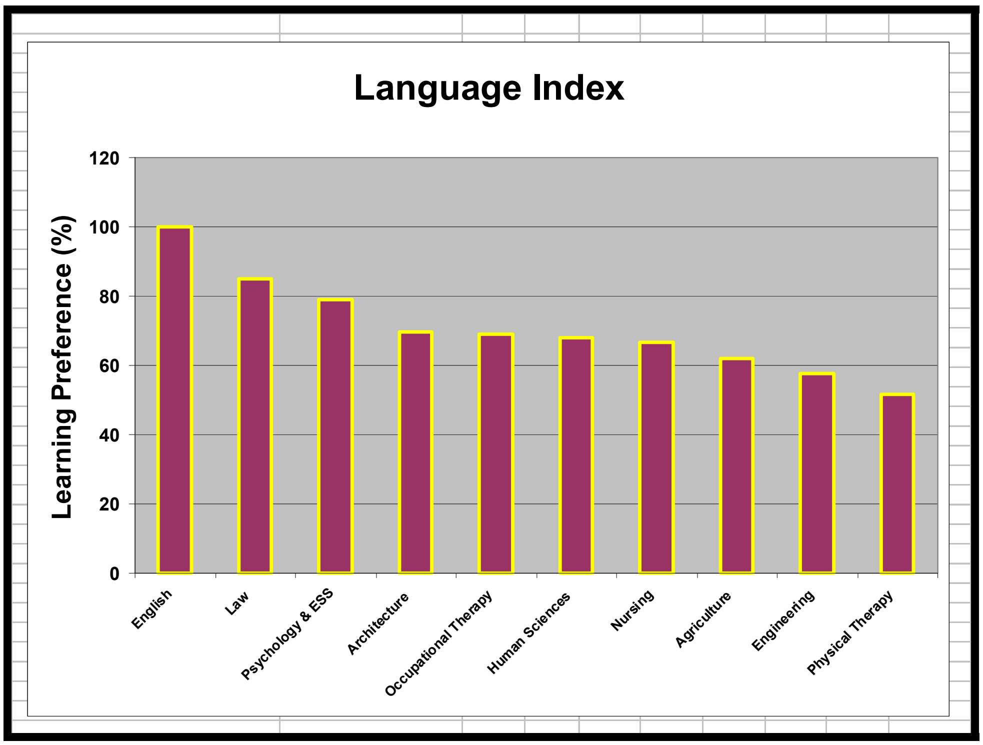

Figure 3. Ordering of majors using language index.

Results from our survey indicate that women generally map about 0.4 lower on the things/people variable than men across all majors. There is less difference between male and female for majors associated with strong people interest (-0.6 to –0.7 range). Mathematically this difference approaches a zero boundary condition as the things/people variable approaches 1.0 or –1.0. The same would be true for the data/ideas variable. Only small differences associated with gender were observed for the data/ideas variable with the current data set. The most likely explanation for these observations is the strong emotional sensitivity of women, which is a right–brain dominate people function.

The relationship between the things/people (male) variable and the things/people (female) variable is shown in Figure 4. Some of the majors listed in Table 1 were not included in this figure because too few male or female students occurred in these majors to establish reliable mean values. Based on these results, we need to adjust the coordinates in our career-mapping website to account for gender differences.

Finally, there appears to be no gender difference associated with learning styles. The majors on both ends of the learning style spectrum in Figure 2 are high in female percentages.

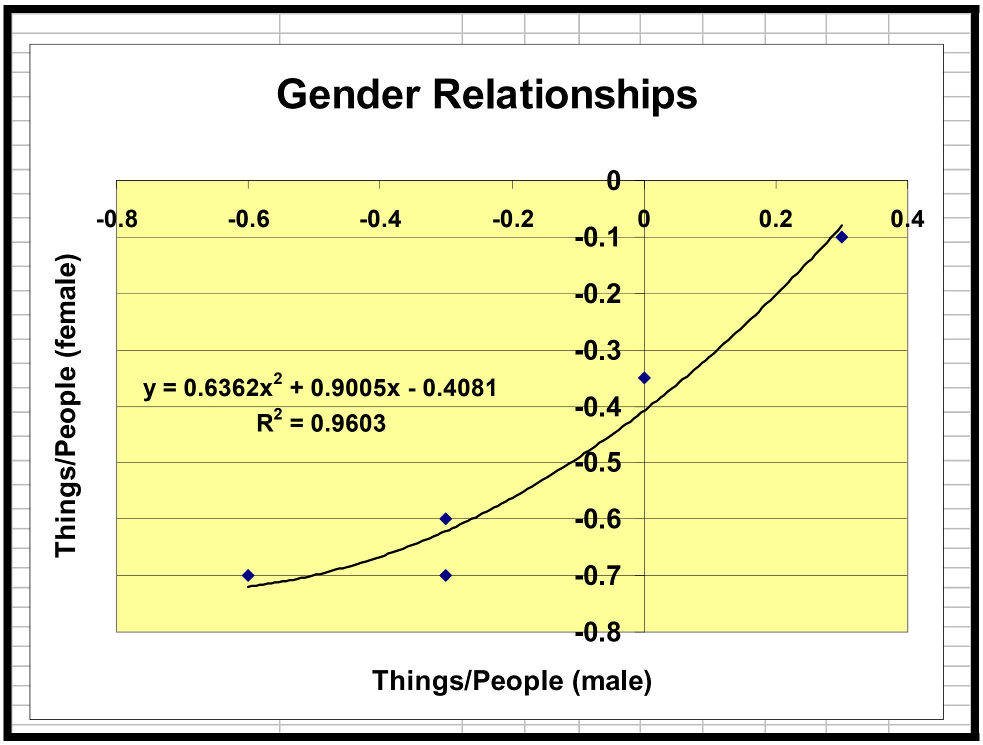

Figure 4. Shift in the things/people variable associated with gender.

Conclusions

Based on the literature and on measurements obtained with the survey reported in this paper, engineers can be defined mathematically by coordinates on a career map. While the process is simple and relatively quick, it is generally reliable in defining the difference between engineers and other professionals, such as nursing, marketing, management of people, etc. Engineers can also be defined mathematically in terms of learning style. This process provides a second independent measurement. Both measurements together provide a more precise mathematical description than either alone. There is evidence that some characteristics are gender dependent, which explains the relatively low number of female students majoring in engineering.

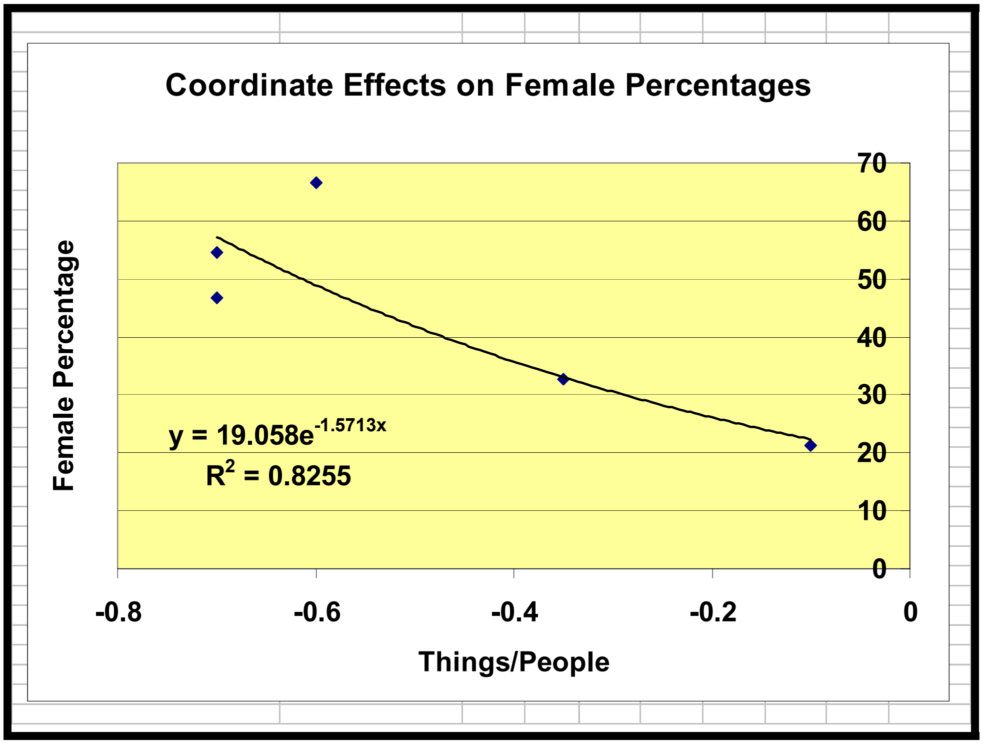

Figure 5. Association of female percentage with the things/people variable.

Felder et al. [8] make the following statement in their paper:

> In short, we believe that the MBTI can provide useful insights into students' learning strengths and weaknesses, but we strongly caution against using it to discourage a student from pursuing engineering or any other curriculum or career. Such a use is unwarranted and unethical.

As with many ethical issues, there are two sides in dealing with information about career selection. We think that MBTI is imprecise and not a reliable tool alone for making a career selection. We, thus, agree that it should not be used to discourage a student from majoring in engineering. On the other hand, it may be just as unethical to know that majors and careers are associated with certain career map coordinates and learning style spectrum and fail to provide this information to the individual. We strongly believe in freedom of choice and use of a full set of information in major selection, including the mathematical nature of an engineer, to make this choice.

Summary

A mathematical description of the characteristics of engineers has been provided. From the distinction associated with gender in this mathematical description, it is possible to explain why some professions are predominantly one gender. This mathematical description enables recruiters and students to better understand the nature of the various majors. Thus, use of the career map and learning style tools can help people to better understand themselves as they relate to professions. While it is desirable to recruit more students into engineering, math, and science professions, it is wise to recruit students with a natural interest toward these majors. Engineers have a precise mathematical nature; people who differ from these characteristics generally are not interested in engineering.

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VERONICA R.BAREFIELD
Veronica is currently a senior civil engineering student at Texas Tech University. She plans to graduate in May of 2003. She is a former president of NSBE at Texas Tech University and Peer Mentor for the College of engineering.

Appendix

Student Survey

College Year (Circle best answer)
1^{st} 2^{nd} 3^{rd} 4^{th} 5^{th}

Major_______________________________________

Department___________________ **College**_____________________

Sex [M / F]

US citizen [Yes/No]

[Right / Left]-**handed**

Race
American Indian
Asian
Black
Hispanic
White
Other__________________

Please order the following statements from most preferred to least preferred:

1 I like to study things such as machines, computers, and natural laws that describe physical systems.
2 I like to study people, courses about people, and ways to help people.
3 I like to study both things and people.
4 I like to work with things, such as machines and systems.
5 I like to work with people.
6 I like to help people.
7 I think logically when I solve problems.
8 I am good at helping people and in working with things.
9 People who work as professionals should learn to use things to help less fortunate people succeed in life.

Most preferred **Least preferred**

Please order the following statements from most preferred to least preferred:

1 I like to invent things.
2 I like to work with both ideas and data.
3 I am good at remembering names of people.
4 I like to collect and organize data.
5 I am about equal in my interest towards data and ideas.
6 I like to discover things.
7 I prefer to work with ideas.
8 I switch back and forth in my preference to used data or ideas.
9 I prefer to remember facts instead of deriving equations.

Most preferred **Least preferred**

Order the following methods for learning from most preferred to least preferred:

1 Seeing pictures and illustrations
2 Reading text with no pictures
3 Listening to others read to you
4 Listening to lectures (non-visual)
5 Seeing figures, graphs, diagrams
6 Following instructions and making things, such as in a chemistry or electronics laboratory
7 Listening to tapes
8 Seeing animation's of principles
9 Observing and doing demonstrations
10 Reading detailed information (mostly words and tables)
11 Working problems
12 Reading simple instructions

Most preferred **Least preferred**

Career Plans (Circle all that apply. If you circle more than one, indicated your top priority with the number 1):

____ Work in industry
____ Operate own business
____ Work in military
____ Work in government
____ Go to graduate school
____ Go to medical school
____ Go to law school
____ Other professional school ______________________________
____ Teach elementary school
____ Teach junior high school
____ Teach high school

Math SAT____________ **Verbal SAT**___________

Math ACT____________ **English ACT**___________

Please have your department or college help you in recording your SAT or ACT scores if you do not remember them.

Finally, check the numbers that you ordered to make sure that you have used each statement (number) only once and that you have used all numbers.

Thank you for your assistance in completing this survey.