AC 2011-2324: ANALYSIS OF CENSUS SURVEY OF MIDDLE SCHOOL STUDENTS' KNOWLEDGE OF ENGINEERS AND ENGINEERING IN A LARGE SUBURBAN K-8 SCHOOL DISTRICT

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Analysis of Census Survey of Middle School Students' Knowledge of Engineers and Engineering in Suburban K-8 School District

Introduction

This paper describes the results of a census survey of middle school student conceptions of career choices, descriptions of engineers and engineering, and interest level in specific examples of engineering given to all grade 6, 7, and 8 students in a suburban school district in Arizona. The purpose of administering this survey was two fold: 1) as an extension of the survey and results described in the National Academy of Education's[1] (NAE) *Changing the Conversation: Messages for Improving Public Understanding of Engineering* and 2) as a pilot study to inform an upcoming district-wide effort to develop a middle-school engineering education program. The survey given to the middle school students is a modified version of the 2008 survey used by the NAE[1] copyright through the National Academy of Sciences. The original NAE study consisted of both qualitative and quantitative research. In an attempt to inform the public, the NAE study created and tested a small number of messages aimed at increasing the publics' awareness of engineering. The survey generated through the NAE study provided a reliable instrument from which we could elicit student conceptions about careers, engineers, and engineering. Previous educational studies have shown that K-12 students have a poor understanding of what engineering is and what engineers do.[2,3] However, most outreach and engineering education activities target high school students, paying less attention to elementary and middle school levels.[1] Unfortunately, by focusing on high school students alone, engineering education efforts miss out on a prime opportunity to mainstream our youth into engineering curriculum. Thus, providing students with positive conceptions of– and experience with engineering, before they develop negative connotation and beliefs will be important. Specifically, this is why the school district with six middle schools collaborated with the authors, who are engineering education researchers at Arizona State University, Tempe, AZ, to conduct a pilot study to help establish baseline data on what their students know about engineers and engineering.

With astounding advancements in technology, the advent of a world economy, and the growing need for energy, the importance of developing a strong domestic engineering base is vital to our nation's continued economic and societal advancement. The role of creative and critical thinkers is more important than ever as innovative and creative new solutions to problems of energy, food, housing, health care, communication, and manufacturing are in demand. Unlike the great technological advances between 1850 and 1950 (i.e., factories, automobiles and airplanes, highways, electrical power, etc.), the current changes are a revolution in the way things are designed, made, and controlled.[4] Low-skill jobs are disappearing; people are switching jobs more often; and demands for highly skilled professionals in developed nations are growing rapidly.[5] The National Science Board[6] indicated that the growth of jobs in the mathematics-intensive science and engineering workforce is outpacing overall job growth by 3:1. With such a need, we must encourage all students to engage with and experience various aspects of engineering early, when in elementary and middle grades. The overall purpose of our work is not to educate every student as an engineer. Our purpose is to give every student a fair and equal opportunity of engaging and experiencing the true nature of engineering and the work of engineers. For such a purpose to become a reality it is necessary to identify: 1) how students are thinking about engineering and 2) how their beliefs change over time. Since much of the previous research has

focused on secondary levels, it is time that we take what has been learned and begin to determine at which stage(s) in the students' development conceptions and beliefs are being generated. For example, if we know that female and minority students are shying away from engineering when they come out of high school because of lack of understanding about the profession, then it is vital to determine at what point they formulate these beliefs and implement effective interventions.

Participants

The sample surveyed consisted of all 6th, 7th, and 8th grade students within a school district located in Arizona. School demographics are shown below in Table 1.

Table 1. Middle School Demographics by Percent

	N	Non-White	Nutrition Program
School 1	1121	40%	26%
School 2	1089	23%	10%
School 3	1027	50%	31%
School 4	1087	55%	45%
School 5	1112	55%	42%
School 6	1057	36%	24%

The study was implemented in this school district at the district's invitation to engineering education researchers at Arizona State University to form a collaborative effort in developing a middle school engineering education program. Furthermore, the district has a unique leadership team, one that is committed to improving science, technology, engineering, and mathematics (STEM) education, eager to support teacher professional development, and excited to support student learning across the disciplines.

Method

A modified version of the National Academy of Sciences' career and engineering beliefs survey[1] was administered through written form. Assessment bundles were created and delivered to each school. Bundles included a copy of the survey (Appendix A), a Scantron (bubble sheet) for student responses, a sheet of drawing paper, and a draw-an-engineer assessment. Although this paper is specific to the survey, it is important to note that administration of the survey also included administration of a drawing assessment. Analysis of the draw-an-engineer assessment data is not reported in this paper. Student participants remained anonymous through a coding system unique to each bundle. Numerically generated codes were affixed to each separate piece of the assessments, to include the envelope in which the assessments were packaged. Coding consisted of a five-digit number, where the first digit identified the school and the remaining four digits identified the student, i.e. 60123 represents school 6 – student 123. Coding started at 0001 and ascended numerically to include the entire population of the school. Once the assessment bundles were in the possession of the individual schools, they were divided among the classrooms by the school's staff. Therefore, researchers had no knowledge of who received which coded assessments. Along with the student assessments, each school bundle included teacher bundles. These bundles included a set of the assessment materials and instructions

describing the process for administering the assessments. University researchers were not present during the administration of the assessments. Upon completion of the assessment, classroom teachers instructed the students to place all portions of the assessment back into the envelope from which they originally came. Researchers collected all of the completed assessment materials, separating, scanning, and inputting all the data into a central database. Students who were absent on the day of the assessment were not included in the database. No attempts were made to return to the schools and give make-up assessments to these students.

Data Analysis

Analysis utilized comparisons of frequency statistics and nonparametric hypothesis testing. Prior to analysis, survey data within the central database were *cleaned* to fit the analysis process. The survey and bubble sheets prompted students for responses A-E, therefore these alpha-responses were converted into numeric-responses; A=1, B=2, …, E=5. Once the data were converted, the database was checked for inappropriate or missing responses for the question that prompted students to identify their current grade. Resulting errors were checked against the student's bubble sheet and corrections were made where possible. Since the frequency calculations were based on grouping by grade level, surveys that could not be identified by grade were eliminated. Once the data were cleaned, select frequencies were calculated (median, mode, percent by mode, and standard deviation) for each question, both separated by grade level and as a whole. A complete list of these numeric values is shown in Table 7, Appendix B.

Phase 1 of Data Analysis

Initial analysis consisted of comparing the mode values of the entire data set (combined 6^{th}, 7^{th}, and 8^{th} grades) across each question. Each question was classified as high, middle, or low. Where a classification of *high* indicated a mode value of 4 or 5, a classification of *middle* indicated a mode value of 3, and a classification of *low* indicated a mode value of 1 or 2. In order to help make comparisons easier, the results are structured to parallel the questions within the survey. As such, each set of results is reported by section: career considerations, knowledge of specific professions, descriptions of engineers/engineering, and appealing examples of engineering.

Although each table shows the responses for each question, discussions will only focus on cumulative responses within the high (mode values of 4 & 5) and low (mode values of 1 & 2) categories.

Table 2 shows the responses for how important each attribute is to the student when considering a career. Responses for this section included: (A=1) Not important at all, (B=2) Not that important, (C=3) Somewhat important, (D=4) Very important, and (E=5) Extremely important. As illustrated in Table 2, students classified *salary*, *interesting work*, and *meaningful work* as important attributes when considering their career.

Career Considerations

Table 2. Frequency Scores (All Grades) for Questions 5-11.

Prompt: Indicate how important each of the following is to you in considering a career.	N	Mode	Percent	SD
Availability	5538	3	32.99	1.125
Challenging Work	5551	3	41.76	1.059
Prestigious	5520	3	40.05	1.107
Recognition	5539	3	40.57	1.025
Salary	5553	4	42.03	0.900
Interesting Work	5550	5	41.64	0.962
Meaningful Work	5546	5	34.87	1.091

Knowledge of Specific Professions

Table 3 shows the responses for how well the student knows the day-to-day operations of a person in a specific profession. Responses for this section included: (A=1) Don't know at all, (B=2) Don't know well, (C=3) Somewhat know, (D=4) Know very well, and (E=5) Know extremely well.

Table 3. Frequency Scores (All Grades) for Questions 12-18.

Prompt: Rate how well you know what a person in the given profession does day-to-day.	N	Mode	Percent	SD
Accountant	5521	3	27.50	1.264
Architect	5526	3	29.35	1.257
Doctor	5527	3	32.21	1.153
Engineer	5513	3	30.78	1.221
Lawyer	5524	3	30.81	1.240
Scientist	5527	3	31.30	1.242
Teacher	5529	5	38.49	1.085

Table 3 indicates that of the seven professions listed, the only profession that students seem to know about is the teacher. Results from NAE[1] survey in *Changing the conversation: Messages for improving public understanding of engineering* study indicated that teens consistently select Doctor, Engineer, and Lawyer as the best choice for a career. Even though the NAE survey prompted teens to indicate the best choice for a career and surveyed a sample of 14 to 17 year-olds, our results uncover a very interesting issue within these choices. Teens may contain beliefs that being a doctor, an engineer, or a lawyer is a preferred profession, however it is possible that they are making these decisions based on information contrary to knowledge about what individuals in the profession actually do on a day-to-day basis. Therefore, a follow-up to this survey would be do determine what information students are using to make these decisions and the sources from which the students are learning the information.

Descriptions of Engineers/Engineering

Table 4 shows the responses for how well a specific word or phrase describes engineers or engineering. Responses for this section included: (A=1) Not well at all, (B=2) Not very well, (C=3) Somewhat well, (D=4) Very well, and (E=5) Extremely well.

Table 4. Frequency Scores (All Grades) for Questions 19-42.

Prompt: Indicate how well you think the word/phrase describes engineers or engineering.	N	Mode	Percent	SD
Boring	5439	1	31.40	1.282
Nerdy	5479	1	27.72	1.344
Sits at desk all day	5446	1	36.19	1.193
Mostly white people	5424	1	40.14	1.213
Businessman	5444	3	29.37	1.199
Fun	5504	3	33.03	1.237
Leaders	5477	3	32.08	1.197
Mostly men	5450	3	28.17	1.301
Rewarding	5418	3	35.97	1.068
Requires too much college	5448	3	32.45	1.209
Well paid	5480	3	32.32	1.096
Well-respected	5451	3	38.08	1.083
Often work outdoors	5444	3	34.15	1.205
Creative	5431	4	32.39	1.101
Get results	5488	4	33.95	1.071
Inventors	5487	4	28.30	1.199
Original thinkers	5481	4	31.16	1.119
Have a positive effect on people's lives	5493	4	30.53	1.120
Problem solvers	5489	4	35.09	1.096
Must be smart to get into the field	5482	4	31.83	1.138
Builds, constructs, and makes things	5456	5	38.09	1.132
Designs, draws, and plans things	5464	5	34.28	1.146
Good at math and science	5470	5	35.92	1.141
Hard working	5495	5	45.17	0.989

As we examined words and phrases that describe engineers and engineering, we begin to see a clear distinction between student conceptions of engineers and engineering. As a whole, we can see from Table 4 that students within this sample do not perceive engineering as boring or comprised of mostly white people; nor do they perceive engineers as nerdy or someone who sits at a desk all day. Whereas, they do believe that engineers are creative, inventors, original thinkers, problem solvers, smart, good at math, hardworking, someone who builds and constructs, and designs and draws; and engineering as having a positive effect on people's everyday lives. Similar to the NAE[1] finding, it is unclear whether students understand how engineers are creative, are inventors, have a positive effect or what it means to build and construct.

Appeal of Engineering Examples

Table 5 shows the responses for how well a specific example of engineering creates interest for them in the field of engineering. Responses for this section included: (A=1) Not appealing at all, (B=2) Not that appealing, (C=3) Somewhat appealing, (D=4) Very appealing, and (E=5) Not a good example. A second part of this question prompted students to indicate whether or not the given example was actually a good example of engineering. For the purposes of this paper, the analysis and discussion will only focus on how appealing the given example sparked interested within the student. Analysis of which examples students found to be good and poor examples of engineering is currently in progress and will not be discussed in this paper.

Table 5. Frequency Scores (All Grades) for Questions 42-69.

Prompt: Indicate how well the given examples create interest for you in the field of engineering.	N	Mode	Percent	SD
Developing new fabrics	4271	1	33.20	1.100
Growing organs for transplants	4286	1	31.31	1.153
Turning deserts to farmland	4326	1	29.22	1.106
Velcro	4060	1	37.44	1.070
Building an acoustically perfect concert hall	4666	3	28.76	1.088
Building the world's longest bridge	4626	3	26.81	1.120
Designing video games	4512	3	29.01	1.114
Developing new foods	4156	3	27.55	1.117
DNA Testing	4432	3	28.16	1.102
Making Homes safer	4582	3	32.61	1.061
Protecting the water supply	4456	3	30.21	1.074
Smart traffic solutions	4652	3	29.21	1.079
Space exploration	4394	3	31.20	1.108
Wind power	4593	3	31.98	1.072
Making smaller, faster computer processors	4704	4	32.08	1.128
Designing better HD TV's	4608	4	31.47	1.090
Building cars that run on alternative fuels	4755	4	34.97	1.117
Designing the world's fastest plane	4776	4	35.74	1.108
Making cars safer	4732	4	34.23	1.062
Using DNA to solve crimes	4309	4	32.72	1.136
Creating machines to do better brain and body scans	4693	4	36.35	1.092
iPod	4257	4	43.67	1.047
Machines that allow the blind to see	4284	4	49.72	1.067
Missile defense systems	4605	4	33.27	1.158
Protecting the rainforest by developing new ways to farm	4370	4	30.48	1.109
Reducing air pollution	4445	4	32.80	1.103
Solar Energy	4524	4	33.60	1.082

We can see from Table 5 that student interests are varied across topics. Students are interested in designing better technologies (better computers, better HD TV's, iPod), but they are not interested in designing video games. They seem to be interested in making cars safer, but not making homes safer. They are interested in designing the world's fastest plane and missile

defense, but not in space exploration; in solving crimes with DNA, but not testing DNA. Environmentally, they are interested in protecting the rainforest by developing new ways to farm and reducing air pollution, but not in protecting the water supply. When considering alternative fuels, they are interested in solar energy and designing cars that run on alternative fuels, but not wind power. In terms of helping, students are interested in machines that help the blind to see and creating better brain and body scanners, but not in smart traffic solutions.

Phase 2 of Data Analysis

The second phase of analysis consisted of significance testing. Significance testing was performed utilizing nonparametric techniques, as the data were gathered from a Likert-Scale (1-5) and visual scans confirmed deviations from normality. A Kruskal-Wallis was used, at $\alpha = .05$, to determine whether differences existed between grades. Follow-up tests used Dunn's Method for pairwise comparisons ($\alpha = .05$), controlling for family-wise error using a Bonferroni correction. A complete list of significant omnibus and pairwise comparison tests is located in Table 8, Appendix C. Statistical testing revealed many significant results. However, with such a large sample size it was important to determine which significant results were meaningful. To determine which results were meaningful, effect sizes were calculated for each set of significant pairwise comparisons. The statistical package used for analysis (SPSS) returns a test statistic value, a standardized-value, and a p-value for all significant pairwise comparisons. The effected size was calculated by dividing the standardized test statistic by the square root of the sum of the two samples being compared. Corrections were made for missing values and ties within the original Kruskal-Wallis ranks. Table 6 includes the sample sizes and modes at each grade level, the standardized test statistics, the p-values, and the effect sizes for each pairwise comparisons (only effect sizes greater than .09 are reported).

Table 6. Significant Pairwise Comparison Results for Effect Sizes > .09.

	6th		7th		8th		Pairwise Comparisons 6th - 8th			7th - 8th		
	N	Mode	N	Mode	N	Mode	z	p	ES	z	p	ES
Q9	1872	5	1835	5	1853	4	6.56	<.001	0.11			
Q17	1867	3	1831	3	1843	3	6.81	<.001	0.11			
Q23	1859	5	1820	5	1830	4	8.35	<.001	0.14	7.01	<.001	0.12
Q37	1832	1	1792	1	1814	1				-6.38	<.001	0.11
Q52	1608	4	1551	4	1586	3	6.98	<.001	0.12	5.13	<.001	0.09
Q54	1580	4	1558	4	1578	4	5.74	<.001	0.10			

Referencing Table 6, we can see that each comparison yielded small effect sizes and there were no effect sizes greater than .09 for comparisons between 6th and 7th grade. A lack of meaningful significant differences between 6th and 7th grade indicates no variation in the way students are thinking about career choice, professional knowledge, descriptions of engineering, or interest in specific engineering examples between 6th and 7th grade. However, we do see differences between 6th and 8th grade and 7th and 8th grade. When comparing the differences between 6th and 8th grade, we can see that within each question 6th grade is responding with significantly higher values that 8th grade (positive z-scores). In this case, students in the 6th grade are more likely to consider meaningful work (work that makes a difference) when considering a career; they have

indicated a greater knowledge of the day-to-day procedures of a scientist; they have a stronger belief that engineers are hard working; and they are more interested in making cars safer and making smaller, faster computer processors. Since these differences exist between 6th and 8th grade, where no differences exist between 6th and 7th or 7th and 8th grade, we can see small changes in students responses that are not large enough to produce statistical significance, but accumulate over time to produce differences between 6th and 8th grade. When comparing the differences between 7th and 8th grade, we can see that 7th grade students have a stronger belief that engineers are hard working, while 8th graders have a stronger belief that engineers are mostly white. These differences indicate that beliefs and conceptions are affected by underlying characteristics of 7th and 8th grade students. Similar to 6th grade students, 7th grade students are more interested in making safer cars than 8th grade students.

Discussion of Results

Although this study cannot speak to the ability of middle school to provoke change over time (as the survey collected a single snapshot of student conceptions and beliefs) it can provide a useful platform from which to engage in further research. In this regard it is important to investigate the results through two avenues: 1) the absence of difference and 2) the existence of difference.

To begin let us discuss the case where survey questions were shown to produce no meaningful differences between grade levels. Within these particular responses we can conclude that whatever beliefs or conceptions the students are bringing to the middle school, it is most likely that their current middle school experiences are not changing these ideas. Understanding this provides an opportunity to target areas of concern and implement action for change. As such, referencing the given results we can produce a set of needs to include researching ways to change values, perceptions, and knowledge within the engineering domain.

Second, where meaningful differences do exist it is important to investigate the true nature behind these differences. As stated above, our results cannot be generalized to signify change over time, i.e. we cannot say that the middle school experience is changing reasoning over time, rather we can say that the responses indicate that reasoning is different across grade level. Therefore, the next step is to determine whether the differences between grade levels can in fact be attributed to experiences in the middle school over time. Finally, we can expand these notions to inform which examples of engineering are most interesting to the students and at what level (where differences exist). With this information we can implement engineering curriculum that pique curiosity and interest in the material.

As mentioned in the introduction, one of the purposes for this work was to expand survey results described in the National Academy of Education's[1] (NAE) *Changing the Conversation: Messages for Improving Public Understanding of Engineering* into the middle-school grades. The data analyses used in the two projects are very different, as the purposes for the NAE study and our study were different. However, a separate set of descriptive statistics were generated from our data in a form that is comparable to the NAE's initial study.[1] The following paragraph will describe the differences and similarities between the data of the two studies. No attempt was made to determine whether differences between reported results are significant, as we did not have access to NAE's data. For a complete list of the comparative data, see data tables in

Appendix C. Tables in Appendix C are separated by topic (Career choices, Familiarity with professions, Describing engineering, and Examples of engineering) and include a descriptive statistic (percentage of students responding at a given level or a mean score) and a ranking within the specific topic. For example, the Interest/Project Sample cell of Table 8 contains 42 (1). These two numbers represent that 42% of the students in the project sample responded "Extremely Important" to the question of "How important is interest when choosing a career?" and that the 42% was the largest response rate within the topic. Referencing Tables 8-10 we can see two characteristics: 1) a majority of the responses for the NAE sample are larger than the responses in our project and 2) the rankings within these tables are fairly consistent (with a few exceptions). Where as, comparisons in Table 11 show a somewhat different result, i.e. differences and rankings seem to be less uniform.

Overall, we can see that the NAE sample seems to place a greater value on interest, making a difference, and challenging work when choosing a career. Both samples are fairly consistent when it comes to their familiarity of specified professions. The NAE sample has a greater perception that engineers need to be good at math, are problem solvers, must be smart, are original thinkers, and are mostly men; and the NAE sample considers cars that run on alternative fuels, space exploration, using DNA to solve crimes, and protecting the rainforest to be more appealing examples of engineering than our project sample.

Next Steps

The data collected from this middle school population contains many rich and informative avenues yet to be analyzed. Our plans for continued investigations include gender differences and factor analysis. Gender difference analysis will follow the same approach as described in the earlier *grade-level analysis*. Continued comparisons on the same data set will be controlled through Bonferroni multiple comparison corrections. Preliminary factor analysis investigations are currently underway. Our hopes are that a meaningful factor analyses will identify specific content domains for student interests and provide categorical representations of how students perceive engineers and engineering. Initial factor analysis procedures showed that Pearson correlations between questions were too low for a meaningful factor analysis. This result was not unexpected, due to the Likert nature of the data. The next step is to check polychoric correlations in the hopes that they will be within minimum and maximum ranges for a meaningful factor analysis.

In addition, we propose to correlate how students responded on the draw-an-engineer assessment with their responses to the NAE survey. We anticipate that analysis of the draw-an-engineer assessment will provide us with knowledge of what students know or don't know about engineers at work. Including a quantitative score that is representative of students' knowledge of the engineer at work as assessed using a scoring rubric will allow us to consider this factor along with student demographics and the survey data about what they know about characteristics of engineers and engineering, and the engineering problems or tasks that students find appealing.

References

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Appendix A

Dear Student,

This survey is to help us understand what you know about engineers and engineering. Your responses will help us know more about what interests you, and what you would like to do when you grow-up. Your responses will also help us create experiences so you can learn and experience engineering-related activities.

In order to keep your responses private, your name will not be associated with your survey responses. All survey responses are anonymous. Each anonymous survey response will receive a unique study ID or code. Please do NOT write your name anywhere on this survey or the attached response bubble sheet.

Please answer the questions honestly; your responses will not be shared with anyone. ***Read each question and "bubble in" your response on the attached bubble sheet. Use a #2 pencil.*** Do NOT write in your name or student id in the bubble sheet.

The questionnaire has five parts:
PART A: Has questions about you; ***your grade level, age, gender, and race/ethnicity.***
PART B: Has questions about ***what you consider is important to you*** in your career.
PART C: Has questions about ***how well you know what people in certain jobs do*** on a day-to-day basis while at work.
PART D: Has questions about ***how well you think*** certain phrases/words describe engineers or engineering.
PART E: Has questions about ***how appealing or interesting*** some examples of engineering are ***to you.***

Thank you for taking the time to respond to this questionnaire.

Acknowledgement
This survey uses questions from the Online Survey that was published in:
National Academy of Engineering. (2008). *Changing the conversation: Messages for improving public understanding of engineering.* Committee on public understanding of engineering messages. Washington DC: National Academies Press.

PART A. Please respond to the following questions with **information about you**:

1. Grade Level: (Select one)
   (A) 6 (B) 7 (C) 8
2. Age: (Select one)
   (A) 11 (B) 12 (C) 13 (D) 14 (E) 15
3. Gender: (Select one)
   (A) Female (B) Male
4. Race/ Ethnicity: (You can select more than one)
   (A) White (B) Black (C) American Indian (D) Asian (E) Hispanic

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PART B. Please indicate how important each of the following is to you in considering which career to get into.

	Not important at all	Not that important	Somewhat important	Very important	Extremely important
5. Salary	A	B	C	D	E
6. Recognition	A	B	C	D	E
7. Interesting Work	A	B	C	D	E
8. Challenging Work	A	B	C	D	E
9. Work that is meaningful (makes a difference)	A	B	C	D	E
10. Availability of jobs in the field	A	B	C	D	E
11. Prestigious field	A	B	C	D	E

PART C. On the following A to E scale, rate how well you know what a person in the given profession does day-to-day.

Profession	Don't know at all	Don't know well	Somewhat Know	Know very well	Know Extremely well
12. Teacher	A	B	C	D	E
13. Doctor	A	B	C	D	E
14. Engineer	A	B	C	D	E
15. Lawyer	A	B	C	D	E
16. Architect	A	B	C	D	E
17. Scientist	A	B	C	D	E
18. Accountant	A	B	C	D	E

PART D. For each of the following, please indicate how well you think the word/phrase describes engineers or the field of engineering:

Describes engineers or the engineering profession …	Not well at all	Not very well	Somewhat well	Very well	Extremely Well
19. Creative	A	B	C	D	E
20. The work is rewarding	A	B	C	D	E
21. Fun	A	B	C	D	E
22. Get results	A	B	C	D	E
23. Hard working	A	B	C	D	E
24. Have a positive effect on people's everyday lives	A	B	C	D	E
25. Inventors	A	B	C	D	E
26. Leaders	A	B	C	D	E
27. Nerdy	A	B	C	D	E
28. Original thinkers	A	B	C	D	E
29. Problem solvers	A	B	C	D	E
30. Well-paid	A	B	C	D	E
31. Must be smart to get into this field	A	B	C	D	E
32. Must be good at math and science	A	B	C	D	E
33. Builds, constructs and makes things	A	B	C	D	E
34. Designs, draws and plans things	A	B	C	D	E
35. Sits at a desk all day	A	B	C	D	E
36. Mostly men	A	B	C	D	E
37. Mostly White people	A	B	C	D	E
38. Well-respected	A	B	C	D	E
39. Requires too many years of school to get a degree	A	B	C	D	E
40. Businessman	A	B	C	D	E
41. Boring	A	B	C	D	E
42. Often work outdoors	A	B	C	D	E

PART E. Please indicate how well the given examples create interest for you in the field of engineering? If you think an example is not a good example of engineering, please indicate that by selecting E (Not a good example).

Examples of Engineering	Not appealing at all	Not that appealing	Somewhat appealing	Very appealing	Not a good example
43. Space exploration	A	B	C	D	E
44. Designing video games	A	B	C	D	E
45. Building an acoustically-perfect concert hall	A	B	C	D	E
46. Designing the world's fastest plane	A	B	C	D	E
47. Developing new foods	A	B	C	D	E
48. Creating machines to do better brain and body scans to diagnose health problems	A	B	C	D	E
49. D.N.A. testing	A	B	C	D	E
50. Using D.N.A. evidence to solve crimes	A	B	C	D	E
51. Building cars that run on alternative fuels	A	B	C	D	E
52. Making cars safer	A	B	C	D	E
53. Growing organs (e.g., kidney, heart, lung) for transplants in humans	A	B	C	D	E
54. Making smaller, faster computer processors	A	B	C	D	E
55. Protecting the rainforest by developing new ways to farm that don't require so much land	A	B	C	D	E
56. Developing new fabrics	A	B	C	D	E
57. Protecting the water supply	A	B	C	D	E
58. Missile defense systems	A	B	C	D	E
59. Smart traffic solutions	A	B	C	D	E
60. Developing better and less expensive High-definition television	A	B	C	D	E
61. Building the world's longest bridge	A	B	C	D	E
62. iPod	A	B	C	D	E
63. Wind power	A	B	C	D	E
64. Making homes safer	A	B	C	D	E
65. Velcro	A	B	C	D	E
66. Reducing air pollution	A	B	C	D	E
67. Turning deserts into farmland	A	B	C	D	E
68. Solar energy	A	B	C	D	E
69. Machines that allow blind people to see	A	B	C	D	E

Appendix B

Table 7. Frequency Statistics

	All Grades				6th				7th				8th				
Question	N	Mode	Percent	SD	N	Median	Mode	SD	N	Median	Mode	SD	N	Median	Mode	SD	p
Q5	5553	4	42.03	0.90	1881	4.00	4	0.92	1833	4	4	0.89	1852	4	4	0.88	0.825
Q6	5539	3	40.57	1.03	1875	3.00	3	1.05	1827	3	3	1.03	1851	3	3	1.00	0.923
Q7	5550	5	41.64	0.96	1877	4.00	5	1.00	1834	4	5	0.95	1853	4	5	0.93	0.000
Q8	5551	3	41.76	1.06	1875	3.00	3	1.05	1835	3	3	1.09	1855	3	3	1.04	0.157
Q9	5546	5	34.87	1.09	1872	4.00	5	1.08	1835	4	5	1.07	1853	4	4	1.11	0.000
Q10	5538	3	32.99	1.12	1871	4.00	3	1.15	1832	4	3	1.15	1849	3	3	1.08	0.400
Q11	5520	3	40.05	1.11	1866	3.00	3	1.12	1824	3	3	1.13	1844	3	3	1.07	0.011
Q12	5529	5	38.49	1.08	1868	4.00	5	1.08	1827	4	5	1.07	1848	4	5	1.10	0.231
Q13	5527	3	32.21	1.15	1866	4.00	3	1.19	1832	3	3	1.14	1843	3	3	1.13	0.014
Q14	5513	3	30.78	1.22	1856	3.00	3	1.24	1827	3	3	1.22	1843	3	3	1.20	0.042
Q15	5524	3	30.81	1.24	1863	3.00	3	1.27	1832	3	3	1.26	1843	3	3	1.19	0.414
Q16	5526	3	29.35	1.26	1862	3.00	3	1.31	1832	3	3	1.25	1846	3	3	1.20	0.077
Q17	5527	3	31.30	1.24	1867	3.00	3	1.27	1831	3	3	1.23	1843	3	3	1.21	0.000
Q18	5521	3	27.50	1.26	1860	3.00	3	1.29	1833	2	3	1.24	1842	3	3	1.25	0.001
Q19	5431	4	32.39	1.10	1838	4.00	3	1.14	1801	4	4	1.09	1806	4	4	1.07	0.007
Q20	5418	3	35.97	1.07	1831	3.00	3	1.11	1795	3	3	1.06	1806	3	3	1.03	0.170
Q21	5504	3	33.03	1.24	1861	3.00	3	1.28	1826	3	3	1.23	1831	3	3	1.20	0.462
Q22	5488	4	33.95	1.07	1854	4.00	4	1.09	1819	4	4	1.06	1829	4	4	1.06	0.152
Q23	5495	5	45.17	0.99	1859	4.00	5	0.95	1820	4	5	0.97	1830	4	4	1.03	0.000
Q24	5493	4	30.53	1.12	1857	4.00	5	1.13	1820	4	4	1.10	1830	4	4	1.12	0.000
Q25	5487	4	28.30	1.20	1853	4.00	5	1.22	1817	4	4	1.20	1831	4	4	1.17	0.914
Q26	5477	3	32.08	1.20	1847	3.00	3	1.23	1814	3	3	1.19	1830	3	3	1.17	0.072
Q27	5479	1	27.72	1.34	1855	2.00	1	1.32	1814	2	1	1.39	1824	3	3	1.31	0.000
Q28	5481	4	31.16	1.12	1849	4.00	3	1.13	1817	4	4	1.11	1829	4	4	1.11	0.576
Q29	5489	4	35.09	1.10	1851	4.00	4	1.13	1817	4	4	1.07	1835	4	4	1.09	0.004
Q30	5480	3	32.32	1.10	1850	4.00	3	1.11	1813	4	3	1.08	1831	4	4	1.10	0.223
Q31	5482	4	31.83	1.14	1849	4.00	4	1.13	1818	4	4	1.14	1829	4	4	1.13	0.002
Q32	5470	5	35.92	1.14	1844	4.00	5	1.14	1814	4	5	1.14	1826	4	5	1.14	0.348
Q33	5456	5	38.09	1.13	1838	4.00	5	1.18	1808	4	5	1.11	1824	4	4	1.11	0.001
Q34	5464	5	34.28	1.15	1838	4.00	5	1.17	1814	4	5	1.12	1826	4	4	1.15	0.001
Q35	5446	1	36.19	1.19	1836	2.00	1	1.19	1806	2	1	1.19	1817	2	1	1.19	0.000
Q36	5450	3	28.17	1.30	1835	3.00	3	1.31	1811	3	3	1.29	1818	3	3	1.29	0.000
Q37	5424	1	40.14	1.21	1832	2.00	1	1.18	1792	2	1	1.19	1814	2	1	1.26	0.000

Q38	5451	3	38.08	1.08	1837	3.00	3	1.10	1805	3	3	1.08	1823	3	3	1.07	0.012
Q39	5448	3	32.45	1.21	1833	3.00	3	1.24	1810	3	3	1.21	1819	3	3	1.18	0.720
Q40	5444	3	29.37	1.20	1831	2.00	3	1.23	1803	2	3	1.20	1824	3	3	1.16	0.041
Q41	5439	1	31.40	1.28	1831	2.00	1	1.27	1806	2	1	1.28	1816	2	1	1.29	0.000
Q42	5444	3	34.15	1.21	1832	3.00	3	1.23	1807	3	3	1.20	1819	3	3	1.18	0.512
Q43	4394	3	31.20	1.11	1433	3.00	3	1.13	1465	3	3	1.12	1506	3	3	1.08	0.462
Q44	4512	3	29.01	1.11	1484	3.00	4	1.14	1516	3	3	1.12	1523	3	3	1.08	0.620
Q45	4666	3	28.76	1.09	1539	3.00	3	1.10	1559	3	3	1.10	1579	3	3	1.06	0.255
Q46	4776	4	35.74	1.11	1614	3.00	4	1.13	1587	3	4	1.10	1587	3	4	1.09	0.002
Q47	4156	3	27.55	1.12	1369	3.00	3	1.12	1367	3	3	1.13	1431	3	3	1.10	0.475
Q48	4693	4	36.35	1.09	1581	3.00	4	1.10	1562	3	4	1.09	1562	3	4	1.08	0.000
Q49	4432	3	28.16	1.10	1451	3.00	1	1.14	1449	3	3	1.10	1545	3	3	1.07	0.645
Q50	4309	4	32.72	1.14	1397	3.00	4	1.17	1414	3	4	1.13	1508	3	4	1.11	0.084
Q51	4755	4	34.97	1.12	1604	3.00	4	1.12	1579	3	4	1.12	1584	3	3	1.11	0.000
Q52	4732	4	34.23	1.06	1608	3.00	4	1.07	1551	3	4	1.05	1586	3	3	1.05	0.000
Q53	4286	1	31.31	1.15	1397	2.00	1	1.16	1413	2	1	1.18	1487	2	1	1.12	0.032
Q54	4704	4	32.08	1.13	1580	3.00	4	1.12	1558	3	4	1.12	1578	3	4	1.13	0.000
Q55	4370	4	30.48	1.11	1438	3.00	4	1.13	1441	3	4	1.11	1503	3	3	1.09	0.000
Q56	4271	1	33.20	1.10	1387	2.00	1	1.13	1406	2	1	1.09	1490	2	1	1.08	0.762
Q57	4456	3	30.21	1.07	1460	3.00	3	1.08	1475	3	4	1.08	1533	3	3	1.05	0.000
Q58	4605	4	33.27	1.16	1511	3.00	4	1.18	1538	3	4	1.16	1569	3	4	1.13	0.033
Q59	4652	3	29.21	1.08	1546	3.00	3	1.08	1529	3	3	1.09	1589	2	3	1.06	0.132
Q60	4608	4	31.47	1.09	1547	3.00	4	1.09	1510	3	4	1.09	1563	3	3	1.09	0.000
Q61	4626	3	26.81	1.12	1539	3.00	3	1.12	1514	3	3[a]	1.12	1586	3	3	1.11	0.315
Q62	4257	4	43.67	1.05	1412	3.00	4	1.04	1437	3	4	1.06	1421	3	4	1.04	0.002
Q63	4593	3	31.98	1.07	1530	3.00	3	1.08	1521	3	3	1.08	1555	3	3	1.06	0.150
Q64	4582	3	32.61	1.06	1529	3.00	4	1.08	1513	3	3	1.06	1551	3	3	1.04	0.000
Q65	4060	1	37.44	1.07	1306	2.00	1	1.08	1343	2	1	1.07	1420	2	1	1.06	0.001
Q66	4445	4	32.80	1.10	1464	3.00	4	1.11	1476	3	4	1.11	1517	3	3	1.09	0.000
Q67	4326	1	29.22	1.11	1405	2.00	1	1.13	1422	2	1	1.09	1510	2	3	1.10	0.055
Q68	4524	4	33.60	1.08	1504	3.00	4	1.09	1515	3	4	1.08	1516	3	3	1.07	0.006
Q69	4284	4	49.72	1.07	1436	4.00	4	1.07	1415	4	4	1.05	1444	3	4	1.08	0.000

[a] Multiple modes are present, the smallest mode is shown.

Appendix B

Table 8. Pairwise Comparison Results

	Pairwise Comparisons											
	6th-7th				6th-8th				7th-8th			
Question	Test Stat	z	p-value	ES	Test Stat	z	p-value	ES	Test Stat	z	p-value	ES
Q5												
Q6												
Q7	-230	-4.662	<.001	-0.077	-252	-5.115	<.001	-0.084				
Q8												
Q9					330	6.562	<.001	0.108	255.284	5.061	<.001	0.083
Q10												
Q11	-124	-2.47	0.014	-0.041					132	2.621	0.009	0.043
Q12												
Q13					141	2.77	0.006	0.045				
Q14					125	2.457	0.014	0.040				
Q15												
Q16												
Q17	184	3.588	<.001	0.059	347.686	6.809	<.001	0.112	164.137	3.201	0.001	0.053
Q18					-133	-2.613	0.009	-0.043	-190	-3.7	<.001	-0.061
Q19									158.86	3.156	0.002	0.053
Q20												
Q21												
Q22												
Q23					406	8.353	<.001	0.138	343	7.013	<.001	0.116
Q24					152	3.023	0.003	0.050	227	4.473	<.001	0.074
Q25												
Q26												
Q27					-260	-5.106	<.001	-0.084	-201	-3.929	<.001	-0.065
Q28												
Q29					129	2.579	0.010	0.042	161	3.205	0.001	0.053
Q30												
Q31					160	3.184	0.001	0.053	153	3.023	0.003	0.050
Q32												
Q33					176	3.546	<.001	0.059	159	3.193	0.001	0.053
Q34					162	3.243	0.001	0.054	169	3.363	0.001	0.056
Q35					-213	-4.266	<.001	-0.071	-157	-3.129	0.002	-0.052
Q36	198	3.879	<.001	0.064	-179	-3.508	<.001	-0.058				

Q37	159	3.188	0.001	0.053	-159	-3.209	0.001	-0.053	-318	-6.376	<.001	-0.106
Q38					131	2.623	0.009	0.043	126	2.522	0.012	0.042
Q39												
Q40					-124	-2.466	0.014	-0.041				
Q41					-194	-3.854	<.001	-0.064	-141	-2.784	0.005	-0.046
Q42												
Q43												
Q44												
Q45												
Q46					125	2.665	0.008	0.047				
Q47												
Q48	-145	-3.133	0.002	-0.056					217	4.67	<.001	0.084
Q49												
Q50												
Q51					193	4.139	<.001	0.073	168	3.577	<.001	0.064
Q52					324	6.984	<.001	0.124	240	5.132	<.001	0.092
Q53	-121	-2.676	0.007	-0.050								
Q54					268	5.738	<.001	0.102	171	3.648	<.001	0.065
Q55					191	4.247	<.001	0.078	173	3.852	<.001	0.071
Q56												
Q57					192	4.225	<.001	0.077	181	4.002	<.001	0.073
Q58					115	2.49	0.013	0.045				
Q59												
Q60					184	4.007	<.001	0.072	129	2.784	0.005	0.050
Q61												
Q62					153	3.522	<.001	0.066				
Q63												
Q64					219	4.774	<.001	0.086	150	3.269	0.001	0.059
Q65					-114	-2.641	0.008	-0.051	-150	-3.501	<.001	-0.067
Q66					181	4.001	<.001	0.073	158	3.484	<.001	0.064
Q67												
Q68					135	2.95	0.003	0.054	112	2.448	0.014	0.044
Q69					198	4.682	<.001	0.087	168	3.925	<.001	0.073

Appendix C

Table 8. Factors in Making Career Choices for "Extremely Important", Percentage (Rank)

Factor	Project Sample 11-15 yrs	NAE Sample 14-17 yrs
Interest	42 (1)	65 (1)
Difference	35 (2)	47 (2)
Salary	34 (3)	34 (3)
Availability	21 (4)	28 (4)
Challenge	12 (7)	28 (4)
Prestige	15 (5)	15 (6)
Recognition	14 (6)	14 (7)

Table 9. Familiarity with Professionals, *Mean Score (Rank)

Factor	Project Sample 11-15 yrs	NAE Sample 14-17 yrs
Teacher	3.95 (1)	4.43 (1)
Doctor	3.45 (2)	3.64 (2)
Lawyer	3.03 (3)	3.17 (3)
Scientist	2.96 (4)	2.73 (4)
Architect	2.85 (5)	2.50 (5)
Engineer	2.83 (6)	2.43 (6)

*NAE sample was rescaled from 1-10 to 1-5.

Table 10. Words That Describe Engineering "Very Well," by Parentage (Rank)

Factor	Project Sample 11-15 yrs	NAE Sample 14-17 yrs
Good at Math	36 (3)	84 (1)
Designs, Draws, Plans	34 (4)	63 (2)
Hard Working	45 (1)	62 (3)
Problem Solvers	30 (5)	62 (3)
Builds, Constructs, Makes Things	38 (2)	59 (5)
Must be Smart	27 (7)	56 (6)
Creative	25 (9)	47 (7)
Well Paid	23 (10)	46 (8)
Original Thinkers	21 (11)	45 (9)
Inventors	28 (6)	41 (10)
Get Results	21 (11)	41 (10)
Mostly Men	12 (19)	37 (12)
Have Positive Effect	27 (7)	36 (13)
Well Respected	16 (15)	34 (14)
Work is Rewarding	17 (13)	32 (15)
Leaders	16 (15)	22 (16)
Work Outdoors	14 (17)	20 (17)
Too Much College	11 (20)	15 (18)
Nerdy	13 (18)	14 (19)
Boring	10 (21)	12 (20)
Mostly White	6 (23)	11 (21)
Fun	17 (13)	9 (22)
Sits at Desk	7 (22)	6 (23)

Table 11. Examples of Engineering Considered "Very Appealing," by Percentage (Rank)

Factor	Project Sample 11-15 yrs	NAE Sample 14-17 yrs
Building Cars That Run on Alternative Fuels	32 (3)	51 (1)
Machines Help Blind To See	42 (1)	48 (2)
Space Exploration	23 (17)	45 (3)
Using DNA To Solve Crimes	27 (12)	43 (4)
Protect Rainforest	25 (14)	40 (5)
Design Video Games	24 (15)	38 (6)
Protect Water Supply	23 (17)	37 (7)
Solar Energy	29 (7)	35 (8)
Growing Organs For Transplant	19 (22)	35 (8)
iPod	35 (2)	34 (10)
Making Better Computers	29 (7)	34 (10)
DNA Testing	19 (22)	34 (10)
Reduce Air Pollution	28 (10)	33 (13)
Create More Advanced MRI Machines	32 (3)	32 (14)
Design The World's Fastest Plane	32 (3)	31 (15)
Safer Cars	31 (6)	31 (15)
Missile Defense	29 (7)	30 (17)
Wind Power	24 (15)	29 (18)
Building an Acoustically Perfect Concert Hall	21 (20)	29 (18)
Design Better HD TV's	28 (10)	28 (20)
Smart Traffic Solutions	19 (22)	28 (20)
Making Homes Safer	27 (12)	27 (22)
Building the World's Longest Bridge	22 (19)	25 (23)
Develop New Foods	20 (21)	25 (23)
Turning Deserts To Farmland	17 (25)	25 (23)
Develop New Fabrics	14 (26)	13 (26)
Velcro	11 (27)	12 (27)