A Retrospective Study of Skills, Traits, Influences, and School Experiences of Talented Engineers

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Abstract

By 2012, an estimated 1.6 million engineers will be needed to support the U.S. job market. The prognosis is poor because the engineering field and characteristics of engineers are not well understood by children, teachers, guidance counselors, and parents. This retrospective study will pilot an instrument designed to identify the influences, skills, and traits of talented engineers that drew them to engineering. The survey was developed using Qualtrics© software. Its link was included in an email that invited 7,000 engineering students and faculty and practicing and retired engineers to participate; 1,000 responded. Using the analysis feature of Qualtrics©, the demographics of the participants and the frequency of their responses were tabulated. The primary influencers identified were family, teachers and counselors, and friends. Several stated that they made the decision to pursue engineering themselves without someone's influence. Skills in math, science, thinking, problem solving, and analytic reasoning were listed as most important. Participants stated that being focused, persistent, ambitious, task-oriented, independent, and interested in many things were key traits of an engineer. The results of this survey helped identify the skills and traits of students who would be a good fit for an engineering future; that curriculum modifications are needed to increase student awareness of engineering; and, that parents, teachers, and counselors need a familiarity of degrees and careers in engineering in order to knowledgeably discuss this field with their children and students. Integrating engineering into the mindset of children and adults may be the start of bringing this country back into the position of technological leadership.

Key Words

K-12 Outreach

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Introduction

The U.S. Department of Labor forecasts that by the year 2012, the United States will need approximately 1.6 million individuals who are engineering educated and trained to fill the engineering employment demand.[24] The purpose of this research project is to identify students who exhibit STEM-based talent and are a good fit for a future in engineering.

Based on the current pipeline, there are not enough students studying engineering today to meet this employment estimate, thus creating an engineering shortage. Concepts that may be related to the solution to the engineering shortage will be explored: 1) the history of the fluctuations in education that may have prompted the current STEM focus of educating younger students about engineering, and 2) the needed awareness and deeper understanding of the engineering field by the individuals, such as teachers, counselors, and parents, who influence and counsel students on their studies and career direction.

In order to identify students who may be a good fit for a future in engineering, the characteristics of today's talented engineers need to be investigated. This retrospective study piloted an instrument designed to identify common childhood characteristics of talented engineers with a mini-study first conducted to refine the primary instrument. One specific research question was considered: What are the common childhood skills, traits, influences, and school experiences of talented engineers?

Situational Analysis

In order to meet this future market demand and address the concern of an engineering shortage, an intervention is necessary to increase the likelihood that students with STEM-based talent will choose engineering as a college major and pursue engineering as a career. Is this nation in a place of possible future inadequate supply? There has always been a demand for engineers, however different reasons for the fluctuation in the supply.[27] During the war, more engineers worked in the armed forces, giving the illusion that there was a shortage, albeit only in the private sector. [27] In the late 40s and early 50s, it was considered a fad to hire an individual with an engineering degree for a job that should have more appropriately been filled by an individual with a Bachelor of Arts degree. Engineers were in great demand, but there was not a shortage.[27] High school-aged male students in the early 50s stated that it was cool to be smart and fashionable to be nerds.[1] They enjoyed taking shop class where they could sketch, measure, design, and create projects. Shop class teachers were often the boys' coaches so students formed close relationships with them. Oftentimes the shop class teachers provided crucial direction to their students regarding their continuing education and future careers. Following their parents' experience with the great depression, and sometimes having come from working class or blue collar families, these young men were encouraged by their teachers and their parents to go to college, study engineering, and get a good-paying job.[1] As such, the U.S. experienced a healthy and continuous supply of engineers for many years.

Fluctuations in Education

The Russians launched Sputnik in 1957 and devastated the technological leadership position that the U.S. held. The Russians' scientific, technological, engineering, and mathematical minds had outsmarted similarly educated American minds. In the midst of the world's recognition bestowed on Russia, this outstanding accomplishment immediately brought to light the deficiencies in the educational system in the United States. Much was published about the neglected minds of the nation's talented students, which prompted a whirlwind of short-lived programs for these bright students. Alongside the focus of education, a concerted effort was initiated in the U.S. to regain its leadership position in technology.

In 1970, the U.S. Commissioner of Education proposed a definition of these bright students, or talented students, in the Marland Report. Children who are capable of high performance are those who have demonstrated general ability, specific academic aptitude, creative or productive thinking, leadership ability, visual and performing arts, and psychomotor ability.[14] By 1990, most states adopted this definition into legislation and provided funding for education programs for these talented children.

A Quiet Crisis in Educating Talented Students, the first chapter in the 1993 U.S. Department of Education's *National Excellence* report, provided another focus on the educational needs of talented students. The report recommended that these students receive higher-level learning opportunities and that teachers receive training on how to implement this high-level curriculum.[22] During this time, many papers about methods and strategies to better reach and teach bright young minds were published.

The results of the Third International Math and Science Study in 1993, 1999, and 2003 indicated that American students consistently performed worse in math and science than students from several other countries, including Singapore, Republic of Korea, Hong Kong, Japan, Netherlands, and Hungary.[19, 20] Concurrently in January 2002, the *No Child Left Behind Act of 2001* was signed into law, making education and promoting educational excellence top priorities. This pledge, to leave no child behind, suggested that *every child* would be provided appropriate educational interventions in order to achieve success in school and in turn, life.[20]

In the most recent attempt to bolster the desire to be a leader in science and technology and "build on [the nation's] successes",[6] the American Competitiveness Initiative was introduced. Substantial funding has been designated for cutting-edge research and development; world-class education focused in science, technology, engineering, and mathematics (STEM); professional development for teachers; and workforce training systems.[6]

For many years, legislation has repeatedly brought the educational issues of our youth to the forefront of its peoples' minds. While legislating improved educational practices and providing a continuum of educational programs that meet all students' needs, including talented students, it seems that in the last fifty years, the United States would by now have a plethora of bright graduating college students preparing to be employed in the fields of science, technology, engineering, and mathematics. It also seems that America would have regained its technological leadership position amongst the other nations. However this does not seem to be the case; "other countries are demonstrating a greater commitment to building their brainpower".[7] Consider these facts and projection:

- In 2004, 350,000 engineers graduated from India's colleges; 70,000 from U.S. colleges.[13]
- In the 2003 Program for International Student Assessment (PISA), the U.S. ranked 27th out of 39 countries. This assessment measures 15-year-olds' ability to solve real-life math problems.[18]
- South Korea, with one-sixth of the U.S. population, graduated more engineers than the United States in 2001 and in 2002.[24]
- From 1985 to 2002, the number of first university engineering degrees awarded in China was up 245%, Japan was up 43%, South Korea was up 176%, and the U.S. was down 22 %.[24]
- U.S. 12th graders ranked almost last in both mathematics and science in TIMMS.[16]
- Since 1983, U.S. engineering colleges awarded more than 50% of all engineering doctoral degrees to foreign nationals.[24]
- In 1970, 50% of the people in the world who held science and engineering doctorates were Americans; by 2010, projections show that figure will drop to 15%.[26]

Based on these data, a new focus on engineering education for students in the U.S. is paramount.

Raising Engineering Awareness

With the past focus on improving education programs and moving toward regaining our technological status, it seems that there would be a large number of students who pursue engineering, one of the four disciplines that make up STEM. However, it is not surprising that there are so few college students pursuing engineering when we do not overtly expose them to the field in their K-12 school curriculum. In the ten years between 2004 and 2014, "jobs requiring science, engineering, or technical training will increase twenty-four percent" to 6.3 million.[26] Will the U.S. be prepared for this demand for critical thinkers fluent in technology? Based on these statistics that represent the past decade, it seems that few high school students have mastered math and science, much less showed an interest in engineering and technology. Declining enrollment and graduation rates in post-secondary engineering programs are plaguing the U.S., and this nation risks continuing its weakened technological position.

In order for the U.S. to regain its leadership position, students need to be taught the principles of engineering and be given positive experiences that may encourage them to pursue an engineering career.[3] Engineering education needs to begin in elementary school while student interest in mathematics and science is still high. About 80% of fourth graders report positive attitudes toward mathematics and science compared to an estimated 33% of eighth graders who report positive attitudes toward mathematics and science.[17]

Integrating Engineering

Integrating engineering into what is currently being taught does not mean adding in a new curriculum into an already overloaded schedule. Oftentimes, engineering is viewed as a separate entity, and teachers run from this notion of having to add more into the curriculum. Claims of no time, minimal knowledge and training, and a lack of confidence added to an attitude of being overworked, result in the conclusion that engineering can not be added into the curriculum.[3] So how can this work?

This integration requires a different perspective in two areas. First, in every unit, engineering concepts exist, and teaching these concepts also means identifying the association with the appropriate engineering field and then affording the students the opportunity to experience engineering by practicing the skills that support the Design Process. Second, this engineering integration will require utilizing different teaching strategies.

There are hundreds of specialty areas of engineering, however the primary fields of engineering are Biological Engineering, Chemical Engineering, Civil Engineering, Electrical Engineering, Industrial/Manufacturing/Production Engineering, Mechanical Engineering, and Software Engineering, and each of these field have a subset of specialty areas. Familiarity with associating content areas in the current curriculum with the fields of engineering is an important first step for teachers.[12]

An engineer implements the Engineering Design Process in all her work. The Process consists of many steps, but the steps aren't as important as understanding the associated skills. The skills of an engineer fall into three categories: technical, communication, and people skills.[8]

The foundation of the necessary technical skills[28] is having a solid understanding of a specific engineering discipline, meeting the educational requirements, and passing the engineering exams.[2] Some of the other technical skills include being an expert in the problem solving process and being able to understand and identify different solutions to problems[2]; thinking creatively and innovatively[4]; understanding how and why things work and interact; being able to analyze, measure, estimate, and calculate; understanding technical drawings and diagrams; and understanding the role and properties of materials.

A unit on bugs and their impact on crops invite a discussion about Agricultural Engineering, and a unit on the human body about Biomedical Engineering; both of these specialty areas are a subset of Biological Engineering. Units on simple machines, recycling, or the environment allow for an introduction to Industrial Engineering. Civil Engineering encompasses typical unit topics such as balances and forces, pollution (subset Environmental), land forms (subset Geotechnical), and weather. A unit on Egypt and using the Pythagorean Theorem to design a pyramid prompt an explanation of using a lever to lift heavy objects, which leads to a discussion of Mechanical Engineering.

Engineering is systems-based[2] and often most topics, situations, or problems will involve more than one engineering specialty area. For example, a unit on transportation falls under Civil Engineering, but a specific discussion on the Magnetic Levitation Train would also require references to Electrical Engineering, Software Engineering, Biological Engineering, and Industrial Engineering.

Communication skills incorporate all of the senses with speaking and writing. An engineer needs to listen and draw information from clients, team members, and experts; visualize different solutions to problems; sees where current solutions need improvement; observe and question information and feasibility; understand others' views to solutions; speak clearly and present information and solutions persuasively[4]; learn and use technical vocabulary; record data, sketch, and draw; and write technically, factually, clearly, and succinctly.[28]

People skills involve leadership skills and teamwork skills as an engineer acts in the role of both leader and team player.[4] An engineer collaborates with team members; is approachable and open to other's ideas; works well with others; communicates easily and frequently with team members; values and solicits expertise of team members[4]; brainstorms effectively; negotiates, manages projects, manages time, and estimates costs; sets and tracks objectives and associated metrics; sees different views to solutions; is ethically oriented[2]; follows the law, engineering codes, and organization guidelines. At any point in a project, an engineer must be willing to start the process or a task over if that is the best solution for the circumstances.

Generating solutions and developing real-world authentic products, both independently and as a team, are key in experiencing engineering. Given the opportunity to work collaboratively offers students a place to practice their communication skills while developing and honing leadership and teamwork skills. Project work will afford the students time to work independently and together, in order to contribute to the team's objectives. In addition to negotiating the direction of the project, the team will also choose the preferred format for their final product. Genuine engineering products could include lab reports, presentations, analyses, technical drawings, graphs, a scale model, and a sketch. An important final step, which is critical in the Engineering Design Process, is the final review and analysis of what worked well and what steps needed improvement. Following this brainstorming activity, the team could write a report on the ideas that were generated and conclude with their recommendations for change.

Many opportunities to increase engineering awareness already exist in the classroom today. Assigning long-term projects for teams of students that incorporate the steps of the Engineering Design Process would benefit students as they practice putting all of the engineering pieces together.

Effective Instruction in Engineering

For students whose strength areas are math and science, there are learning preferences and teaching strategies that are better suited for these content areas. Similarly, there are ideal strategies for teaching engineering that are being implemented in colleges today. Driven by components of the engineering design process, the preferred strategies are Problem Based

Learning, Critical and Creative Thinking, and Socratic Dialogue, as all three foster inquisitiveness.[23]

Problem Based Learning (PBL) is based on being given an authentic problem to be solved. The problem is typically messy and complex. Questions need asking, information needs gathering, and choices need pondering. The original problem could change in the middle of the analysis process or even morph into another problem. As often in real life, there isn't one right solution. Because of the nature of an ill-structured problem, engaging in critical and creative thinking is imperative. Probing questions foster the unveiling of information that is necessary in identifying the unknowns of the problem and exploring all options of possible solutions. The questioning process, the basis of Socratic Dialogue, is collaborative and cooperative, where everyone works together to gain a deeper understanding of the problem and the solution. It involves both critical thinking and good communication skills. Authentic and relevant problem solving are the basis of Problem Based Learning, and PBL is one of the preferred strategies in today's college engineering classrooms, as evidenced by the Aerospace Engineering Program at Massachusetts Institute of Technology.[5]

Incorporating the steps in the Engineering Design Process and the associated engineering skills will help the students experience those that are typical in engineering jobs. Since engineers are given problems to solve, using PBL in the classroom models that which an engineers experiences in the field. PBL offers this combination of investigation, research, questioning, discussion, and creative, critical, and innovative thinking.

Influences in the Pursuit of Engineering

Besides increasing awareness of engineering in students' classrooms, teachers and guidance counselors need a more solid understanding of the field of engineering as well as the fit of engineering study with students who show STEM-based strengths.

The Extraordinary Women Engineers Project (EWEP) is lead by the WGBH Educational Foundation in conjunction with a coalition of 55 professional engineering associations. This group is interested in understanding why more female students aren't pursuing an engineering degree much less a career in engineering. Their initial premise is that it is a perception problem in that the primary influencers on female students' degree program recommendations and career choices do not understand engineering. WGBH conducted a qualitative research study and their results indicate that teachers, school counselors, parents, peers, and the media are "key influencers and resources for information gathering".[11] The priority order of influence is parents, friend and peers, teachers and siblings, school counselors and professionals.

The survey further showed that "many teachers and counselors do not feel prepared to help their students explore the engineering profession, with one quarter of respondents reporting that they don't know enough to help students learn more about engineering".[11] Their recommendations when asked about engineering were to use the internet or read about engineering on university websites. Parents were also not comfortable recommending engineering because of their lack of knowledge on the field. The exception was parents who studied or worked in the science field.

The EWEP coalition recommends that training opportunities be created to promote engineering education and careers to girls, their parents, and educators … school counselors and teachers".[11]

Skills and Traits of Engineers Described by Professional Organizations

"The word *engineer* has its roots in the Latin word *ingeniator*, which means ingenious, to devise in the sense of construct, or craftsmanship. Several other words are related to ingeniator, including *ingenuity*".[15] An engineer is defined by her own set of attributes, skills, traits, and educational accomplishments.

The National Academy of Sciences developed a list of engineer's attributes that are key to the success of the engineering profession: strong analytical skills, practical ingenuity (skill in planning, combining and adapting), creativity, good communication, master of business and management, leadership, possess high ethical standards, strong sense of professionalism, dynamism, agility, resilience, flexibility, and lifelong learners.[15]

The Boeing Company, manufacturer of commercial jetliners and military aircraft combined, is a long-standing supporter of K-12, college, and university programs, and because of its business, takes an interest in employing engineers that possess a specific set of attributes:

- a solid understanding of engineering science fundamentals,
- a good understanding of design and manufacturing processes,
- a multi-disciplinary, *systems* perspective,
- a basic understanding of the *context* in which engineering is practiced,
- good communication skills,
- high ethical standards,
- an ability to think both critically and creatively - independently and cooperatively,
- flexibility; the ability and self-confidence to adapt to rapid or major change,
- curiosity and a desire to learn for life, and
- a profound understanding of the importance of teamwork.[4]

Accreditation Board for Engineering and Technology (ABET) was originally established in 1932 as an accreditation agency. Over the years, it expanded to evaluate engineering and engineering technology degree programs. The organization is a "federation of twenty-eight professional and technical societies" with practicing professionals from "academe, government, and industry" as its individual members.[2] ABET issued engineering program outcomes that "are statements that describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that students acquire in their matriculation through the program"[2]:

- an ability to
    - apply knowledge of mathematics, science, and engineering,
    - design and conduct experiments, as well as to analyze and interpret data,
    - design a system, component, or process to meet desired needs within realistic constraints,
    - function on multidisciplinary teams,
    - identify, formulate, and solve engineering problems,

    - communicate effectively,
    - use the techniques, skills, and modern engineering tools necessary for engineering practice,
- an understanding of professional and ethical responsibility,
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context,
- a recognition of the need for, and an ability to engage in, life-long learning, and
- a knowledge of contemporary issues.[2]

The majority of the traits, skills, and attributes listed by these three organizations were very similar; the differences may be attributed to their varying purpose.

Characteristics of Engineers Presented to Children

Engineering is "the application of math and science to create something of value from our natural resources".[9] Engineers "synthesize, solve problems, and innovate".[9] They develop and invent the *new*, and also improve the *old*. Engineers are good at math and science, are good problem solvers, and apply math and science to solve problems creatively; are creative and imaginative; like to build new things and improve the way things work; have good communication skills; and like to work in teams.[21] "Engineers are able to adapt to a changing environment".[10]

Degreed Engineers' Beliefs of their Skills and Traits: A Mini-Study

In order to refine the categories and questions for the pilot survey, one question was emailed on September 21, 2007 to a convenience sample of twelve practicing and retired 40-75 year old engineers. The question sent to the engineers was: *Please describe the school experiences, influences, skills, and traits that impacted your decision to become an engineer*. Eleven engineers responded. Table 1 lists and tabulates the characteristics that were revealed by the eleven engineers in this mini-study.

Table 1

Engineer's Influences, Skills, and Traits

Characteristic	Quantity
family member or family friend persuaded individual to pursue engineering	10
other person persuaded individual to pursue engineering [a]	10
really enjoys/interested in math and science	10
continually interested in learning new things; enjoys learning	8
influenced by toys [b]	8
likes to design, enjoys drawing/drafting, enjoys building models	8

thinker (analytical, logical)	7
interest, passion	6
likes to take things apart and put back together, understands how things work	6
creative, captured imagination	5
grade skipped, involved in gifted program, high achiever	5
persistent, tenacious, ambitious	5
solves problems and puzzles	4
involved in summer internship or co-op experience	3
wanting to please family member	3
detail oriented	2
enjoys challenge	2
ethically oriented	2
inquisitive, curious	2
ability to see connections	1
focus	1
looks at all possibilities	1
understands cause and effect	1
viewed as exciting career	1
visualizes solution	1

Note. [a] guidance counselor, math teacher, science teacher, mentor, role model. [b] chemistry set, calculator, Legos©, Lincoln Logs©, Erector Set©, K'Nex©.

Despite the fact that there are hundreds of fields of engineering, this small study identified some of the core skills and traits that engineers typically exhibit regardless of the field they choose.

Method

Subjects

The sample in this study consisted of three groups: engineering students, engineering professors, and practicing and retired engineers. The engineering students and faculty were based at a large STEM-based university. The director in the Undergraduate Engineering Recruitment facilitated anonymously identifying the students and professors. The practicing and retired engineers were targeted using several avenues. Personal contacts, and degreed engineers identified from internet searches, alumni organizations, and referrals made up the third group of practicing and retired engineers. It was necessary that this sample meet the qualifications of having a degree from an engineering program, so choosing this specific sample was deliberate. The sample total based on emails sent was 7,382 engineering students, engineering professors, and practicing and retired engineers. The breakdown of the three group sizes is 6,379 students, 343 professors, and 660 practicing or retired engineering professionals.

Instrument

This study is piloting a new instrument that will identify common childhood experiences, influences, skills, and traits of talented engineers. The choice of attributes offered in this new instrument was based on the refinement of the pilot survey. This instrument is a survey that was developed using Qualtrics© survey software. A link to the survey was established by Qualtrics© after the survey development was completed.

The survey was designed with three groupings of a total of 14 questions, although these groupings are transparent to the participant:

-first grouping: the participant is asked three demographic questions regarding her location (city, state, and country), gender, and age (fill-in-the-blank); and, to provide her initials in order to distinguish between duplicate submissions by the same individual from identical submissions by different participants.

-second grouping: the participant is asked a question relative to school and employment status (check-all-that-apply); to identify each major for each degree earned or in-progress (fill-in-the-blank); and, to rank order her favorite four subjects in High School.

-third grouping: the participant is asked to identify the people who influenced her decision to pursue engineering (check-all-that-apply); her skills and attributes that may have influenced her decision to pursue engineering (check-all-that-apply); her traits that may have influenced her decision to pursue engineering (check-all-that-apply); the toys/games/items she enjoyed playing with that might have inspired her to study engineering (check-all-that-apply); and the participant is asked to rank in order what and/or who influenced her decision to study engineering.

Several questions had an option for the participant to fill in their own answer just in case the choices provided were did not include their preferred answers.

The survey was developed in November and early December 2007.

Procedures

During the first two weeks of January, messages were emailed to the targeted individuals asking that they participate in the survey. A brief statement was provided explaining that their input identifying their childhood experiences, influences, skills, and traits that drew them to pursue engineering would be helpful in the implementation of engineering curriculum in grade school. The Qualtrics© link to the survey was included in the email message that was sent to the participants. Another statement in the email explained that participation in the survey is voluntary, the survey is anonymous, and that the participant had to be 18 years old to participate. A final statement assured the participant that the survey was estimated to take less than 10 minutes to complete.

The Qualtrics© survey does not require any special computer hardware or software. Once the participant clicks on the link provided in the email message that she received, she is immediately directed to the survey page. The participant has the option to back up and change her answers. Once the participant completes and submits her survey, a final thank you message is displayed.

A count of the emails initiated by this author is being tracked. However in the email, the recipients were invited to forward the survey link to their colleagues so the count of the total sample is not possible as survey invitations that are being forwarded by the original group of identified participants cannot be tracked.

Data is collected in real-time. At any time, this author can log into the Qualtrics© website and the results can be viewed and analyzed. Qualtrics© provides a substantial offering of data management. The data collected from the survey can be exported into standard statistical analysis software packages. Participants' data can be viewed individually or in groups; data trends can be viewed through a filter; and a variety of graphics options are available.

Results

The survey was emailed to 7,382 individuals; however the number of people who were forwarded the survey is unknown. The Qualtrics© software provided the statistical results based on the software's criteria for completed surveys, which totaled 1,008 surveys. Of these, 777 were undergraduate students, 59 faculty, and 172 practicing or retired engineers (see Table 2). The group with the largest proportion (26.1%) of respondents was the practicing and retired engineers.

Table 2

Participants by Status

	Emailed	Responded	Proportion
Undergraduate Students	6,379	777	12.2%
Faculty	343	59	17.2%
Practicing/Retired	660	172	26.1%
TOTAL:	7,382	1,008	13.65%

The largest age group was the 16 to 23 year old group, represented by 524 males and 235 females. The smallest age group was the over 66 year old group, represented by only 25 respondents and all were male. The middle 3 groups, 24 to 36, 37 to 49, and 50 to 65 years old, were similarly represented by about 20% females and 80% males (see Table 3).

Table 3

Demographic Data of Participants by Age Group

	Count Column % Row %	16 – 23	24 – 36	37 – 49	50 – 65	>66	Totals
		AGE GROUPS					
GENDER	Female	235 31% 84.5%	15 20.8% 5.4%	17 20% 6.1%	11 17.7% 4%	0 0% 0%	278 27.7%
	Male	524 69% 72.3%	57 79.2% 7.9%	68 80% 9.4%	51 82.3% 7%	25 100% 3.4%	725 72.3%
	Totals	759 75.7%	72 7.2%	85 8.5%	62 6.2%	25 2.5%	1,003 100%

Participants could select more than one individual who influenced their decision to pursue engineering (see Table 4). The top nine choices of individuals who influenced the participants' decision were ordered by age group because the 16 to 23 year old group was much larger than the other four age groups. The primary influencer for all of the age groups was a parent who was not an engineer. The next influencer was the other parent who was not an engineer or the participant decided to pursue engineering without anyone's influence. All age groups listed their science and math teachers but in different positions of influence. Friends or neighbors who were engineers were identified in all age groups, and a relative who was an engineer was identified in four of the five age groups. The participants' guidance counselor was identified as influential in the three higher age groups, but not identified in the lower two age groups' lists of the top nine influencers.

Table 4

Influencers on Individual's Decision to Pursue Engineering

16 – 23	24 – 36	37 – 49	50 – 65	>66
My Mom who was not an Engineer	My Dad who was not an Engineer	My Dad who was not an Engineer	My Dad who was not an Engineer	My Dad who was not an Engineer
My Dad who was not an Engineer	My Mom who was not an Engineer	I decided without anyone's influence	I decided without anyone's influence	My Mom who was not an Engineer

My Science Teacher	My Science Teacher	My Dad who was an Engineer	My Guidance Counselor	Other
My Dad who was an Engineer	I decided without anyone’s influence	My Mom who was not an Engineer	A friend or neighbor who was an Engineer	My Dad who was an Engineer
I decided without anyone’s influence	A relative who was an Engineer	My Math Teacher	My Mom who was not an Engineer	My Math Teacher
My Math Teacher	My Math Teacher	My Science Teacher	A relative who was an Engineer	My Science Teacher
A relative who was an Engineer	My Dad who was an Engineer	My Guidance Counselor	My Dad who was an Engineer	A friend or neighbor who was an Engineer
A friend or neighbor who was an Engineer	Other	A friend or neighbor who was an Engineer	My Math Teacher	A relative who was an Engineer
My Technology Teacher	A friend or neighbor who was an Engineer	Other	My Science Teacher	My Guidance Counselor

Note. Descending order

In Table 5, the top eight skills and attributes that the participants selected are ordered by age group. More than one skill and attribute that influenced their decision to pursue engineering could be selected. All five age groups chose being good at math as the primary skill that influenced them. In the lower two and higher two age groups, the next two choices included being good at science. For the middle age group, being good in science was the sixth skill in order of importance. The top four age groups chose analytical reasoning and problem solving in their top eight selections, however the youngest age group picked neither.

Table 5

Skills and Attributes that Influenced Decision to Pursue Engineering

16 – 23	24 – 36	37 – 49	50 – 65	>66
good at math	good at math	good at math	good at math	good at math
good at science	enjoy math	enjoy problem solving	enjoy science	good at science

enjoy science	good at science	good at analytical reasoning	good at science	think about how things work
like learning new things	good at analytical reasoning	logical thinker	good at problem solving	enjoy problem solving
enjoy math	enjoy problem solving	good at problem solving	enjoy math	enjoy math
think about how things work	good at problem solving	good at science	good at analytical reasoning	enjoy science
logical thinker	enjoy science	think about how things work	enjoy making/ building things	good at analytical reasoning
enjoy challenge	like learning new things	enjoy science	enjoy problem solving	like learning new things

Note. Descending order

The most important traits that influenced the participants' decision to pursue engineering are detailed by age group in Table 6. The participants could check more than one trait. Each age group selected, but ordered differently, the same nine traits out of their top twelve traits. The 3 different traits between the age groups were common: sense of humor, perfectionistic, keen observer, self-directed, ethically-oriented, and good self concept.

Table 6

Top Traits that Influenced Decision to Pursue Engineering

16 – 23	24 – 36	37 – 49	50 – 65	>66
interested in a lot of things	interested in a lot of things	need for logic	task-oriented	self-directed
need for logic	task-oriented	persistent	focused	task-oriented
focused	need for logic	focused	persistent	focused
persistent	persistent	self-directed	self-directed	independent
ambitious	ambitious	task-oriented	honest	persistent
honest	focused	interested in a lot of things	interested in a lot of things	honest

task-oriented	need for accuracy	independent	need for logic	ambitious
independent	perfectionistic	need for accuracy	ambitious	interested in a lot of things
has a sense of humor	honest	ambitious	independent	need for accuracy
need for accuracy	independent	honest	ethically-oriented	ethically-oriented
perfectionistic	keen observer	keen observer	need for accuracy	good self concept
keen observer	has a sense of humor	perfectionistic	has a sense of humor	need for logic

Note. Descending order

Each age group chose a unique set of toys and games that might have inspired the m to pursue engineering (see Table 7). The only toys the age groups had in common were Lincoln Logs©, a bicycle, and board games or Monopoly©. Participants from all three younger age groups, totaling 724 individuals, selected Legos© as their first choice toy. Tinker Toys© and Erector Set© were two common toys in the four higher age groups; however they were not chosen in the youngest age group. Computer games and Xbox/Nintendo/Playstation/Wii© were only chosen in the youngest age group.

Table 7

Toys and Games that Might have Inspired Participant to Pursue Engineering

16 – 23	24 – 36	37 – 49	50 – 65	>66
Legos©	Legos©	Legos©	Electric Trains	Erector Set©
K'Nex©	Lincoln Logs©	Lincoln Logs©	Lincoln Log©	Electric Trains
Computer Games	Cards	Bicycle	Erector Set©	Bicycle
Lincoln Logs©	Tinker Toys©	Erector Set©	Tinker Toys©	Chemistry Set
Board Games	Bicycle	Blocks	Chemistry Set	Lincoln Logs©
Xbox/Nintendo/ Playstation/Wii©	Blocks	Monopoly©	Monopoly©	Monopoly©
Bicycle	Erector Set©	Tinker Toys©	Blocks	Tinker Toys©

Cards	Monopoly©	Board games	Chess©
Chess©			Bicycle

Note. Descending order

The responses to these questions were order by age group because the number of participants varied greatly between the younger group and the four older groups. The younger group represented 75% of the participants so the responses were separated to insure that all the choices of each group would be accurately reported.

Discussion

The responses from this survey provided both a fuller picture of the characteristics of talented engineering students, academic engineers, and practicing engineers, and a clearer understanding of the individuals who influenced the participants in their various stages of pursuing engineering. Since these participants represent a span in time from the 1950s to today, many witnessed the exploration, attempts, and advancements in every field of engineering that took place during the 20^{th} century. These life experiences may have influenced their responses. This is evident in the choice of popular toys and games which seemed representative of the technology at the time.

The National Academy of Sciences, Boeing Company, and ABET stated that thinking skills, analytical skills, and problem solving skills are key for engineers. They explain that these skills are used in every step of the design process, so it is imperative that engineers develop and hone these skills. These three organizations also stated that having a desire for lifelong learning was an important attribute for engineers. Society's needs change frequently and technology advances rapidly; both drive an engineer to adapt to constant learning. The participants' responses were similar to those of the National Academy of Sciences, Boeing Company, and ABET.

There are certain traits that engineers exhibit during the various steps of the design process used to solve problems and invent solutions. These traits are inherent in the engineer's personality, ingrained in their thinking, part of their core. All five groups of engineers chose the same top nine traits, although in different orders, because these traits are essential to those in the profession.

The results of the qualitative research study that WGBH conducted indicated that the priority order of influence was parents, friend and peers, teachers and siblings, school counselors and professionals. In this study, parents were unanimously the primary influencer, but the surprising high-ranked response was the participant, who stated that the decision was made without anyone's influence. Follow-up studies with the participants could help clarify the circumstances behind this unilateral decision to pursue engineering. With the guidance counselor absent in the choices of the younger-aged groups, follow-up studies could investigate if the issue was centered on the guidance counselor being unfamiliar with the engineering field.

Engineering concepts are beginning to be incorporated in some schools' curriculum; however it is clearly missing in most. As teachers become more familiar and comfortable with the concepts of engineering, follow-up studies could assess teachers' willingness to raise engineering awareness in their classroom. Based on the results of this survey, engineering content and concepts and associated engineering skills and traits should be integrated into the curriculum. In order to create interest in students to pursue engineering study, it would be beneficial to bring this same awareness and education to the students' influencers identified in this survey, parents, teachers, and guidance counselors. Integrating engineering into the mindset of children and adults may help bring this country back into the position of technological leadership.

The opportunities in engineering are growing at the same rate as the exploding technological advancements. Most children with STEM-based strengths have interests or passions that can be discovered and realized with exposure to the different fields of engineering. Any student who dreams of being an engineer can fulfill her goals; those in the field of engineering don't want to leave any child with these kinds of dreams behind.

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