2016 STEAM/STEM Education Conference, Honolulu HI

IDENTIFYING ENGINEERS AT THE HIGH-SCHOOL LEVEL

Topic Area: Academic Advising and Counseling

Format: Paper

ABSTRACT:

Career guidance matches natural abilities to corresponding careers. An aptitude in science and math is associated with many disciplines that include science, medicine, education and engineering. This paper identifies the skills that specifically indicate potential success in engineering, as defined by Engineers Canada.

Leo Stocco, PhD, PEng
Senior Instructor
The Department of Electrical and Computer Engineering
The University of British Columbia
2332 Main Mall, Vancouver, BC, Canada, V6T 1Z4
leos@ece.ubc.ca
(604) 822-0166

INTRODUCTION

Engineering is a self-regulated profession in Canada. Engineers Canada [1] is an impartial organization that certifies engineering programs in Canada that fulfill the national accreditation criteria. An accredited engineering program qualifies its graduates for licensure as professional engineers in the associated Canadian province in which the engineers intend to practice, such as APEGBC [2] in British Columbia. Once licensed, a professional engineer is bound by a code of conduct and ethics that protects the safety and well-being of their profession, their colleagues, and the general public.

To maintain their accreditation status, post-secondary institutions develop engineering programs that satisfy the criteria which is an open-ended definition of minimum course content and learning objectives. Since the criteria outlines the fundamental content and goals of all accredited Canadian engineering programs, it is a valuable metric for identifying secondary school students who demonstrate an aptitude in the associated activities and outcomes. It may come as a surprise that much of the criteria is non-technical and relates to skills which people outside of engineering may not associate with engineering, such as communication, teamwork and ethics. This sharply contrasts the engineering stereotype and causes many particularly qualified students to overlook engineering and not be guided toward it.

Eligibility for accreditation comprises two categories, Accreditation Units (AU) and Graduate Attributes (GA). Accreditation Units account for the hours of course content devoted to broadly defined subject areas, and Graduate Attributes account for the characteristics that a student is expected to develop as a result of their participation in the program.

ACCREDITATION UNITS

Accreditation Units are divided into the following categories.

- Mathematics
- Natural Science
- Complementary Studies
- Engineering Science
- Engineering Design
- Laboratory Experience and Safety Procedures

Mathematics, Natural Science and Complementary Studies are well understood and require no explanation. They are commonly associated with a variety of career paths that include science, math, engineering, architecture, nursing, pharmacy, and medicine. It is the other two categories that distinguish an engineering program from all others and may be used to identify students with a particular aptitude for engineering.

Engineering Science is taught by a register Professional Engineer (P.Eng) and consists of scientific theory and how it is put into practice. It does not include scientific observations that have not yet found an application, which distinguishes it from Natural Science. For example, quantum mechanics was born as a theoretical concept exclusive to natural science courses, but eventually evolved into the backbone of electrical engineering courses which deal with semi-conductor device operation and design.

Engineering Design courses apply material learned in Engineering Science courses to real-world design problems. They are taught by a P.Eng and are typically application specific such as Semiconductor Device Design, Airplane Wing Design, Truss and Support Structure Design, or Chemical Adhesive Design. They typically include a hands-on component where students develop unique designs and either build and test them, or simulate them using software evaluation tools. This component may include both assignments and projects. Assignments are small, well defined problems that give students experience adapting an existing design to a specific set of numeric requirements. Projects are larger, more vaguely defined problems that give students more freedom to be innovative and creative.

Laboratory Experience accounts for time spent gaining hands-on experience with engineering design and analysis tools and may involve building prototypes, using lab equipment, running simulations, or taking field trips to sites where engineering designs are put in practice. Laboratory Experience may either be a component of an Engineering Design course, or may comprise an entire course, with associated Engineering Science courses listed as pre or co-requisites. Dedicated Laboratory Experience courses may be a collection of small, well defined lab experiments, or a larger, open-ended design project.

Project courses integrate a variety of disciplines and topics into an open-ended design problem. They generally occur at the end of a year, or at the end of a program, and are performed in groups so that students can integrate the skills they have accumulated in various courses into a single, larger, and more diverse activity. They develop not only technical skills, but also organizational, budgeting, management, and time management skills. In addition, they practice the engineering design process which may be used to address any engineering design problem.

The engineering design process is as follows.

1. Clearly define the problem in terms of requirements (must-haves), constraints (limitations), and goals (non-essential desires).
2. Identify a diverse range of viable alternatives.
3. Eliminate any alternative that violates any one of the identified requirements or constraints.
4. Rank the remaining alternative in term of how well they satisfy the goals.
5. Implement the best alternative.
6. Evaluate the selected alternative through testing and measurement.

Safety Procedures are an integral part of most courses involving Engineering Design, and all courses involving Laboratory Experience. It incorporates safety standard of both engineering designs and engineering design projects. This includes the safety of the engineers developing the design, any workers involved in the production of the design, and the general public who may use or be exposed to the design. These safety standards are cited by the code of conduct and ethics that is enforced by Engineers Canada and the associated provincial professional engineering associations.

GRADUATE ATTRIBUTES

Graduate Attributes are divided into the following categories.

- Design
    - Problem Analysis
    - Knowledge Base
        - Investigation
        - Life-Long Learning
- Use of Engineering Tools
- Individual and Team Work
    - Communication Skills
    - Economics and Project Management
- Professionalism
    - Impact of Engineering on Society and the Environment
    - Ethics and Equity

Design broadly refers to the engineering design process as a whole. It involves defining the problem, proposing design alternatives, eliminating unviable alternatives, choosing the best remaining alternative, implementing it and evaluating it. The most innovative designs apply sound technical principles in ways that have never seen before. Strong design skills are therefore a marriage between a large and diverse knowledge base, artistry, creativity, and impartiality.

Problem Analysis is the first step in the engineering design process. It is the process of clearly defining a problem in terms of requirements (must-haves), constraints (obstacles), and goals (non-essential desires). It is a rigorous process that requires attention to detail.

Knowledge Base is the collection of knowledge a student acquires and has at their disposal to apply to problem solving. It includes a mastery of natural science, math, engineering science and laboratory experience, in a chosen discipline. It is the fundamental set of building blocks upon which any engineering design is based. Developing a large knowledge base requires independent study, and a genuine interest in the subject matter.

Investigation is a self-directed effort to augment one's own knowledge base, in the context of a given problem. It may involve self-study, experimentation, consultation, or any other means of developing a particular expertise that is required to shed light on the problem at hand. The process of investigation combines resourcefulness and rigour.

Life-Long Learning is a propensity to acquire knowledge either out of necessity, or for the sheer pleasure of it. It is a side-effect of a genuine interest in engineering science and related topics. It is demonstrated by learning activities that are performed with no direct incentives such as grades or compensation. It requires self-motivation and is often evident in a student's choice of hobbies.

Use of Engineering Tools combines an awareness of available engineering tools with the necessary experience to use, or learn to use those tools as part of the engineering design process. It may also involve choosing between tools that performs similar tasks. Engineering tools are diverse and may include lab equipment, software applications, or outsourcing services. Selecting and using the correct tools for a job requires a well-rounded knowledge of the available tools and the hands-on skills to use them effectively.

Individual Work requires sufficient self-motivation to work independently and unassisted. It may be demonstrated through individual assignments, or by the execution and on-time delivery of individually allocated tasks within a team project.

Team Work is a combination of organization, management, time management and a variety of soft skills such as cooperativeness, diplomacy, fairness, respect, and open-mindedness (ability to resolve conflicts). Effective teams have a leader that allocates tasks and tracks progress. All team members are assigned equal work that is not duplicated and is scheduled so that milestones are reached in a logical order with minimal time conflicts and inter-dependencies.

Communication Skills includes presenting work and ideas in informal discussions, formal presentations, and technical documents. Informal discussions occur continually throughout the design process. Informal communication skills include sketching, clear and concise verbalization, and listening skills. Formal oral communication skills include an ability to summarize and articulate a complex topic into a clear, well organized, interesting, and easily digested form. Written communication skills include strong grammar, efficient and well organized writing, and effective use of clearly defined and annotated figures and graphs.

Economics and Project Management corresponds to the financial and human resource allocation that is devoted to completing a project. It demands an awareness of non-technical constraints and organization skills which are used to allocate the available resources to each of the tasks in a project so that they are completed on time, on budget, and in a logical order to minimize interdependencies and delays.

Professionalism is an ability to separate work from personal bias or emotion. It includes effectively delivering or accepting constructive criticism, impartially evaluating one's own or another's work, making decisions without racial, gender or sexual bias, accepting responsibility for unfavourable circumstances, and treating colleagues in a respectful manner. It is an ability to control personal biases and may be broadly summarized as combining the awareness of what constitutes appropriate behaviour with the self-control to carry it out.

Impact of Engineering on Society and the Environment is the consideration of external factors that may be affected by a particular engineering solution. It includes pollution, health and safety, quality of life, public acceptance and approval, and emotional distress, among others. It combines an awareness of non-obvious side-effects with an altruistic desire to provide benefits to society with minimal disruption or societal cost.

Ethics and Equity is a sense of moral obligation that is applied to any work being done or any expected outcome. It includes considerations such as cruelty to any living beings, favoring the welfare of particular demographics over others, taking unfair advantage of groups of individuals such as minors or the elderly, or anything else that may not necessarily be illegal, but tests one's sense of right and wrong.

SUMMARY AND CONCLUSIONS

The attributes that are typically associate with strong engineering candidates are technical in nature. Although math and science skills are certainly a pre-requisite for success in engineering, there are many softer skills that have been identified by the professional engineering associations to be equally essential ingredients for success in the engineering profession. They are implied by the graduate attributes that partially define an accredited engineering program.

The following descriptors are associated with the graduate attributes:

Design	Knowledgeable	Artistic	Creative	Impartial
Problem Analysis	Rigorous			
Knowledge Base	Independent	Studious	Interested	
Investigation	Resourceful	Rigorous		
Life-Long Learning	Interested	Self-motivated		
Use of Eng. Tools	Well-rounded	Hands-on		
Individual Work	Self-motivated	Punctual		
Team Work	Cooperative	Diplomatic	Open-minded	Respectful
Communication Skills	Organized	Concise	Articulate	Listener
Economics & Project Man.	Aware	Organized	Punctual	Logical
Professionalism	Unbiased	Diplomatic	Responsible	Respectful
Impact of Eng. on Soc. & Env.	Aware	Altruistic		
Ethics & Equity	Moral	Kind	Fair	

It is proposed that having a clear understanding of these attributes would better allow guidance counsellors to direct students who may otherwise be overlooked, toward engineering as a profession.

REFERENCES

[1] Engineers Canada website, http://www.engineerscanada.ca

[2] The Association of Professional Engineers and Geoscientists of British Columbia website, http://www.apeg.bc.ca