Early and Continuous Exposure to Engineering as a Profession: Career Imprinting in Grades PK-12

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Abstract

In recent years, there has been much discussion about declining interest in engineering programs throughout U.S. colleges and universities. Several possible causes for the decline have been identified and are fodder for debate: (1) PK-12 educational systems are not adequately preparing students to comprehend the connections among science, technology, engineering, and mathematics (STEM) and future career opportunities and (2) College engineering curricula need to be more aligned with the real world needs of business and industry. Several programs such as STEM summer programs and internships have been developed to address these issues, but to a large extent, such programs are short-term based. Additionally, they mostly target high school students; are only applicable in one grade level; or are one time project-based events. What would be the impact of systematically exposing PK through high school students to engineering concepts, applications, and career opportunities on a long-term, continuous basis at each grade level? If students are constantly reminded that engineering is part of their daily lives, this could generate a lifetime interest in the engineering profession and engage them in benefiting humanity.

The authors are proposing "career imprinting," similar to that espoused by Harvard Professor Monica C. Higgins in the field of business, as a possible strategy to increasing students' awareness of and appreciation for careers in engineering. The objective would be to not only assist students in cultivating and acquiring grade level appropriate, as well as discipline-specific basic skills needed by engineers, but also to help them develop the personal characteristics that are essential to be successful in the engineering profession. By connecting "engineering as a profession" to the development of these skills and characteristics, students may be sparked to have an interest in engineering and can become "imprinted" to consider careers in the field.

Introduction

It is a well-documented fact that the needs of the engineering industry are not being met by the current educational system. Although some of the nation's post-secondary institutions are experiencing growth in *individual* engineering programs, an overall general disinterest in engineering as a profession continues to capture the attention of admissions officers, college deans, and others who are concerned about the future of the engineering profession. Trends show that even though there has been rapid expansion in technological advancements and a growing demand for U.S. engineers, student graduation rates indicate that schools of engineering have been unable to supply neither the number nor the quality of engineers required by the engineering industry. The number of first-year college students expressing an interest in engineering as a major has declined over the last five years[1]. Unfortunately, some of the students who are now choosing non-engineering majors are among those who possess the strongest math and science backgrounds.

Why are students leaving engineering? Some reasons include poor performance of the faculty, mostly poor teaching; poor student performance, especially in math; restrictive coursework; misperceptions of engineering; isolation, and the need for educational reform[2]. Interestingly, more females are proficient in math and sciences are leaving engineering than males[2]. More women and minorities are getting into medical school, which could be a lot more challenging and rewarding than engineering. They, however, (females especially) get a sense of increased social worth and value to society than they perceive they would receive in the engineering profession. There has, therefore, been a general decline in the number of females and minorities entering into engineering in spite of aggressive recruitment efforts by most post-secondary institutions.

Due to the current globalization trends and increased outsourcing of jobs, engineers not only need to have analytical skills, but must also be able to function in multicultural environments; possess leadership, management and interdisciplinary skills; and understand the need to be engaged in lifelong learning. There is also a growing need for engineers to be involved in policy-making, especially at congressional and senatorial levels. Some professionals have identified the significant amount of outsourcing of engineering jobs to countries such as India and China as a contributing factor connected to the declining interest in engineering. Furthermore, the quality of undergraduate engineers is not meeting the needs of the engineering industry. The American Society of Civil Engineers (ASCE), for example, is calling for the attainment of a Body of Knowledge (BOK) for entry into the practice of civil engineering at a professional level[3]. To attain the BOK, ASCE proposes appropriate technical experience be combined with the completion of either a master's degree or approximately 30 upper division undergraduate credits. There are some who believe that this move, although a step in the right direction to improve the quality of current practicing engineers, might also be detrimental to post-secondary institutions' recruitment efforts targeted at increasing the number of future engineers.

Several programs, sponsored by the National Science Foundation (NSF), American Society of Engineering Education (ASEE), National Society of Professional Engineers (NSPE), universities and other institutions have been implemented in an attempt to address the challenges associated with recruitment and retention of prospective engineers, especially in such underrepresented groups as women and minorities. The groups targeted have varied depending on the program sponsors' goals and objectives, and at times there have been some overlaps. Focusing on the improvement of math, science, and technology skills was the thrust of the vast majority of such programs, which were primarily designed to reach students at the high school and collegiate levels. Such programs have oftentimes enticed participants to become involved by offering opportunities for them to engage in real-world, hands-on engineering projects. The NSF has played a key role in the funding of such programs--many of which have been implemented by ASEE, NSPE, K-12 schools, colleges, universities, and community action groups. As a result, efforts to develop curriculum, establish engineering education coalitions, promote research, and encourage the use of alternative pedagogies in an effort to enhance teaching and learning in STEM areas, including engineering, have benefitted from the availability of NSF grant opportunities.

Although a considerable number of these programs have generally been viewed as effective and helpful, they have not resulted in systematic changes in the perception and retention of engineers[2]. What steps must then be taken to ensure that there will be a sufficient number of engineers for the next century? Today's world has changed significantly over the past 10 years. The younger generation has an uncanny ability to use all kinds of electronic gadgets. None of us can now imagine a world without computers or other electronic appliances. Now is, therefore, the perfect time to introduce PK-12 students to the role of engineers in our changing world. If engineering is presented in a manner that emphasizes its relevance to our daily lives, the impact will be tremendous. Such infusion must start as early as possible in the educational development of students and be consistently reinforced throughout each grade level, if a long-term solution to the current decline in interest in engineering is to be found. Short-term programs have their place in attracting students, but systematic and consistent exposure to the various components of engineering must be infused into current PK-12 curriculums if a significant increase in the number of future engineers is to be achieved.

While there is a multitude of ways in which to encourage PK-12 students to develop interest in engineering as a profession, the authors subscribe to the belief that systemic change will only occur with a high rate of success when a well-developed strategy, that includes a systematic long-term grade level appropriate infusion of engineering concepts and ideas into all subject-matter disciplines of PK-12 curriculums. One such strategy, the authors suggest, is based on the principle of "career imprinting" to create interest in engineering as a profession.

Proposed Strategy: Creating Engineering Career Imprints

As previously mentioned, compared to 20-30 years ago, technology now plays a more significant role in day-to-day living and youngsters seem to naturally develop an aptitude for electronics. Why is this the case today? Some would argue that at an early age, today's youth see the need and relevance, for example, of operating the TV remote or video game joystick. Youngsters, therefore, identify with and embrace the idea that technology is a necessary part of their daily lives. Thus, without much thought or even detailed instructions in some cases, they seem to be able to master a wide range of technology-based and relevant operations. The desire to be able to play a video game, or record a TV program for later viewing, instills a precise or particular imprint that causes a young person to be motivated to learn. Thus, the capacity for youngsters to be able to apply complex principles at an early age cannot be dismissed. This is how engineering should be introduced in our elementary and high schools--make it relevant to everyday living and students will most probably embrace it as a "way of life."

Using the above example, the desire to play and enjoy a video game served as a motivator for a "need" the youth identified. Fulfilling the need most definitely left an imprint as a new capability and confidence were developed. The question is now, how do we initially incorporate this idea in the current curriculum? The strategy we are proposing consists of building an "engineering relevance and application" component into current PK-12 curriculums.

The proposed strategy is derived from the concept of career imprinting espoused by Harvard Business School Professor Monica C. Higgins who has described organizational career imprints as "the set of capabilities and connections, coupled with the confidence and cognition that a group of individuals share as a result of their career experiences at a common employer during a particular period in time"[4]. In our case, the "classroom experiences" students have during "school at each grade level" serve to imprint them. In this particular case, we refer to these experiences as "*Engineering career imprints*." The objective of the strategy we propose is to help students develop the capabilities to make the right connections and build the confidence and cognition to become engineers through a series of shared experiences by introducing them to engineering via the subject matter to which they are exposed. The desired outcome is that the "imprints" made through these exposures will create linkages for students between engineering and course content, as well as among students' learning environments, personal daily lives and the various engineering disciplines. This may then lead students to select careers in engineering.

We are proposing consistent and systematic exposure at each grade level. By implementing this strategy, it is anticipated that students would be imprinted with some qualities or characteristics typical of engineers by the end of each grade level. These qualities could be further developed at the next grade level or qualities could be grouped by grade level. That is, some qualities could be addressed in certain grades and not in others. The emphasis of the proposed strategy, however, would be to provide to students--by the end of 12th grade--well-rounded exposure to most facets of engineering thereby making the concepts presented to them more relevant and minimizing misperceptions about the profession.

Professor Higgins stated that career imprints bring opportunities as well as constraints depending on how it [career imprinting] is applied[4]. In an educational institution setting, we would be seeking opportunities to spark interest in students by using *engineering career imprints* within the constraints of the regular curriculum, to encourage them to choose engineering as a profession. This strategy should, therefore, not be rigid, but flexible enough to allow variation from state to state as well as from school district to school and district, and even from classroom to classroom, if necessary. Some of the variations would depend on schools' structure and the qualifications of teachers.

The implementation of this "career imprinting" strategy should ensure that:

- Students acquire and develop grade level, developmentally appropriate, specific knowledge, skills and *capabilities*.
- Students make the right *connections*. This should involve addressing the social impact of engineering, relevance to daily life and connections to the various engineering disciplines. These connections will, no doubt, vary from individual to individual depending not only on students' individual personality traits, but also on their additional exposure to engineering outside of the school's curriculum.
- Students at all grade levels would be nurtured to develop the *confidence* needed to succeed not only in math, science and technology based courses, but also in non-STEM courses.
- Students would widen their *cognition* of stereotypes, taken-for-granted assumptions, myths, and so forth that may affect their desire and/or ability to succeed. Examples of some stereotypes include: "Minorities cannot succeed in engineering because of poor math and science skills"; Engineering is boring and has no social relevance; and Engineers are nerds.

A schematic representation of our strategy, as shown in Figure 1.0, consists of four levels. The first level involves the establishment of a relationship between engineering concepts and subject matter covered in the current PK-12 curriculum. The inclusion of engineering would involve several components such as applications through projects, field trips, and so forth with the objective of enabling students to make the right connections to the relevance of engineering to their present day living. This level will make use of some of ongoing STEM-based subject matter instruction where the application of fundamental principles is already taught. Instruction in non-STEM-based subject matter areas would still be used without much content modification, but opportunities to discuss relationship of instructional content to engineering and or technology would be systematically introduced where appropriate. Two examples of how this could be incorporated into the course content for math and social studies are shown in Figures 2.0 and 3.0.

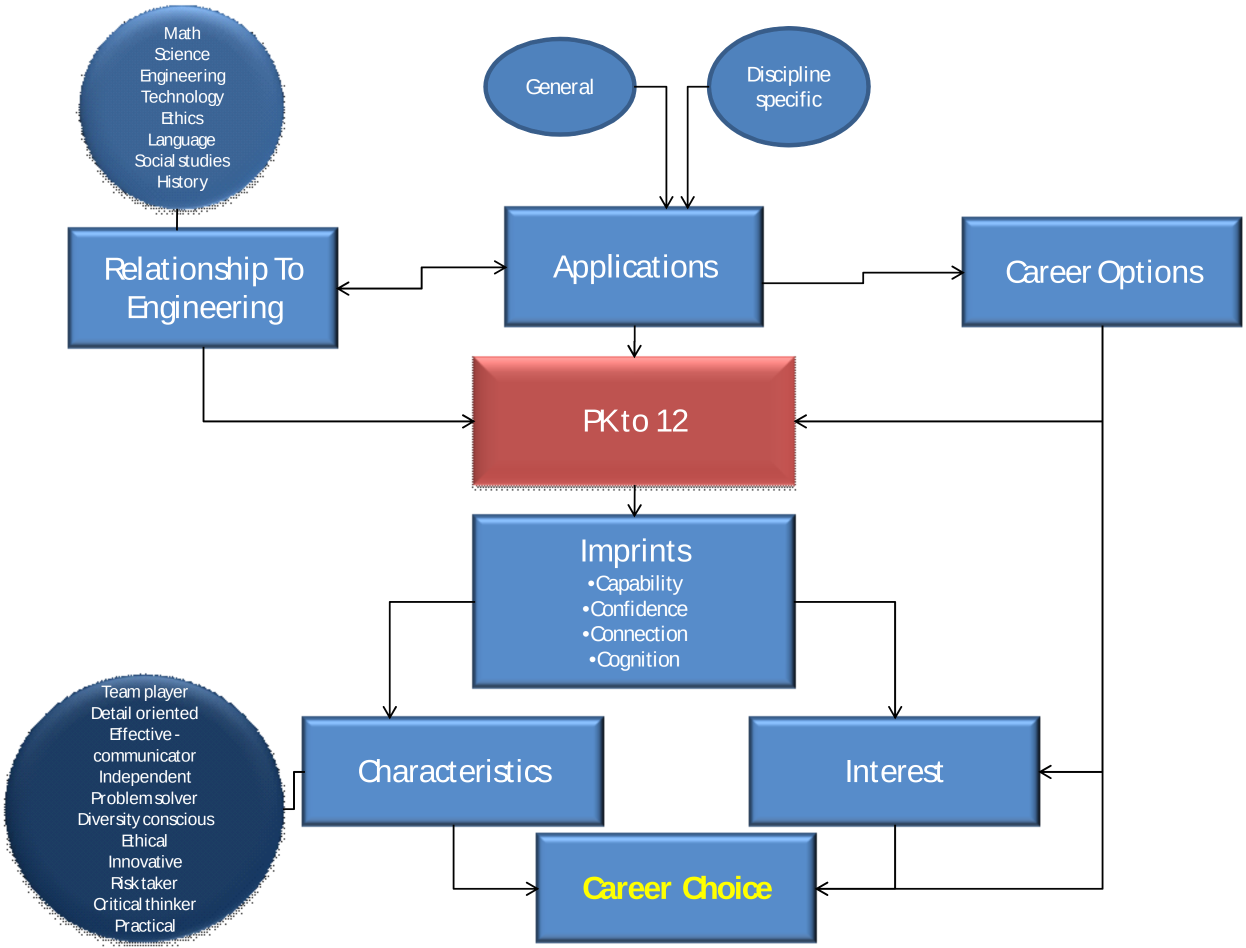

Figure 1.0: Schematics of Proposed Strategy

Emphasis is placed on encouraging students to recognize the relevance of engineering to their own lives, as they now know it. Key points that would be highlighted in both examples include:

- What led to the development of such principles?
- How was society impacted then, as well as now?
- Was there any technological/engineering advancement as a result of this?
- Who were the key players?
- How has or how can this be applied?
- Example application(s)/events specific to each grade level.
- Relevance to present day--making it personal.
- Are the right connections being made? Putting it all together.

It is anticipated that both teaching and learning will be enhanced when teachers intentionally make connections between the subject matter being taught and real-world examples that demonstrate how engineering impacts the world in general and the quality of their students' lives in particular.

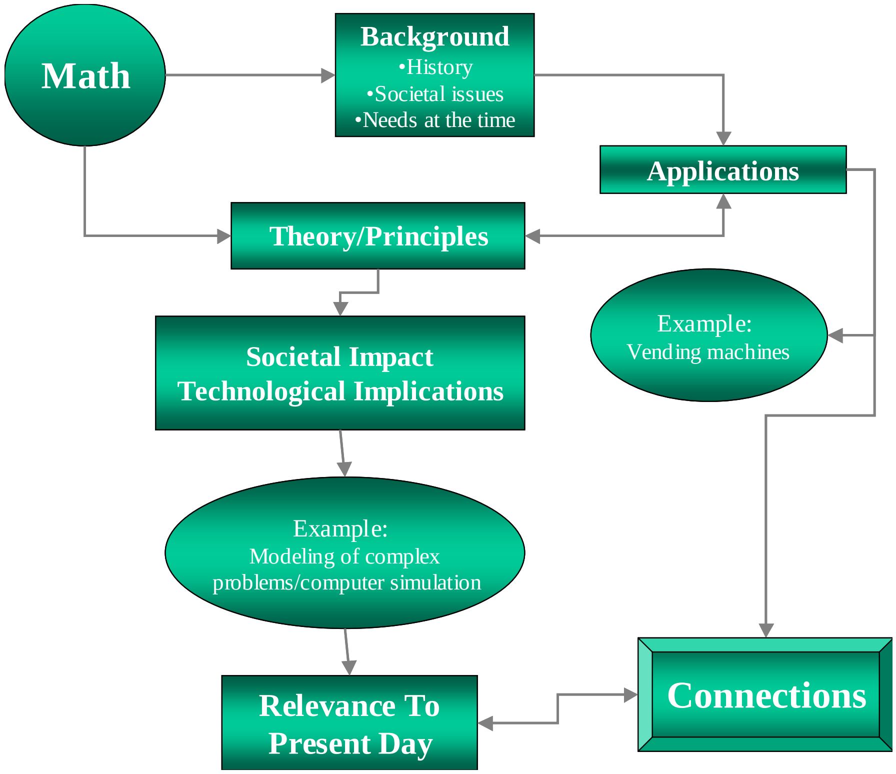

Figure 2.0: Example Course Structure -Schematics of Strategy for Math

At the end of each grade year, an assessment would be conducted to evaluate the level of capability, connections, confidence and cognition (4C's) developed. This is the second level of the model and can be seen as taking stock of the quality and amount of imprinting already accomplished. It is to be noted that formative assessments can be administered throughout the school year as a way of monitoring students' progress, rather than waiting until the completion of summative evaluations at the conclusion of the school year. The assessment need not be complicated. Grade level appropriateness and the acquisition of evidence to document a student's level of attainment relative to the 4C's would be emphasized.

At the third level, students who have developed some characteristics and interest in engineering could then receive more detailed instructions such as STEM AP courses, honors classes, and dual-enrollment courses could be used. This level could be broken into two or more streams. In one stream, as already mentioned, students would receive more detailed instruction and preparation for college engineering courses--applicable to upper high school students. Another stream would include further infusion and exposure to hands-on engineering projects, and/or reinforcement of other grade-level specific fundamentals. Students' personal interests in various components of engineering as well as their skills and abilities in fundamental courses would dictate the extent to which they would be involved in self-directed projects and activities related to engineering as a profession.

The fourth and final level is where students make career choices. Having developed the 4C's through systematic exposure to engineering principles and applications, there is a strong possibility that students would be motivated to pursue careers in engineering.

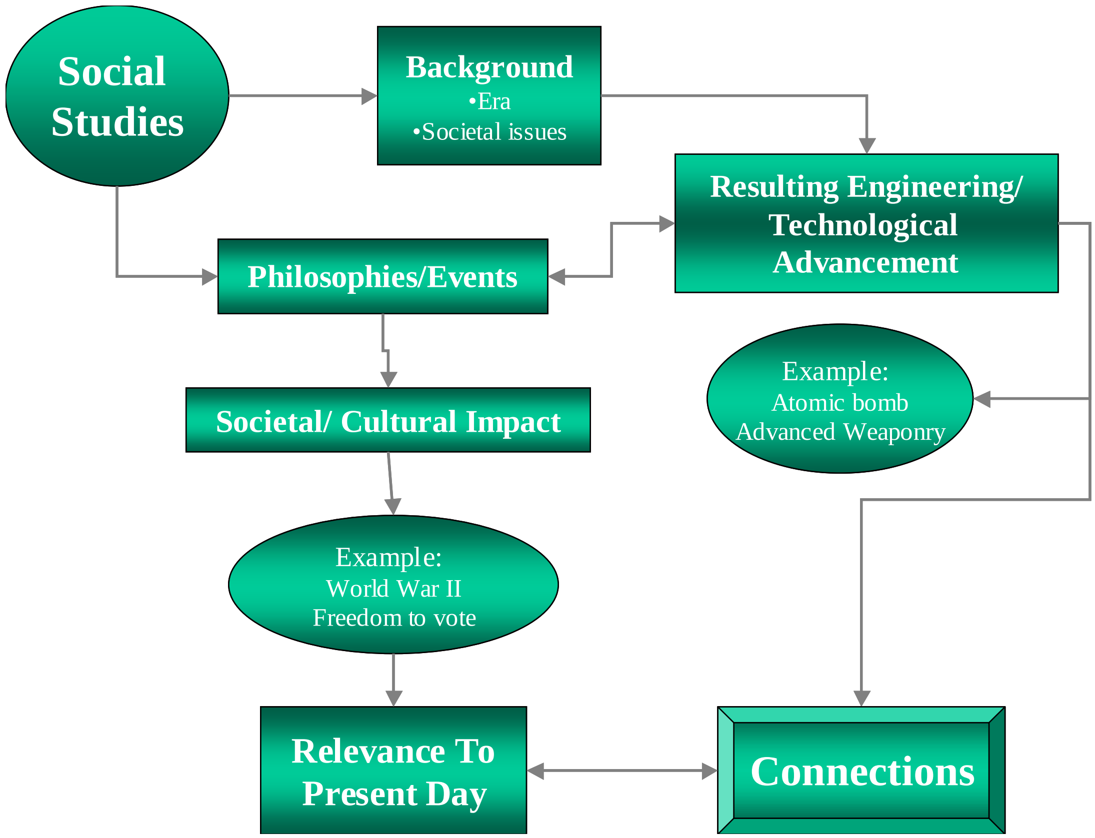

Figure 3.0: Example Implementation-Schematics of Strategy for Social Studies

Challenges

Infusion of "career imprinting" into day-to-day PK-12 classroom instruction, although not a complex process, will certainly have its special challenges. One challenge , which must not be overlooked, is the school administrator who may not be willing to support the efforts of teachers who are engaging students in more hands-on "fun" activities and projects rather than the common "follow the textbook" path of instruction.

Teachers will need to have access to a wider range of resources that can enable them to clearly demonstrate connections between what they are teaching and engineering, be they in the form of "what engineers do" or "the impact of engineering" on our world. Such resources might include, but certainly would not be limited to the following: study trips, guest speakers, special supplies and equipment for projects, audio-visual aids, subscriptions to professional publications, children's and young adults' books about engineering and engineers; attendance at conferences such as ASEE, faculty-engineer exchanges and so forth.

The current focus on school accountability as demonstrated by students' performance on standardized achievement tests poses a special challenge due to the rigid instructional schedules that are often used in today's classrooms. Career imprinting will require teachers to have more latitude in their daily instructional schedules so that they can guiltlessly deviate from "test-prep or time on task driven" agendas to "capitalizing on teachable moments" and "student interest-driven" agendas which will afford learners the opportunity to reflect on what they are learning. This will not only make it possible for them to put their newly acquired knowledge into the context of what they already know but will also motivate them to think outside of the proverbial “box,” thereby setting the stage for more personal internalization of the role of engineers and their impact on society. Through the development of such personal affinity between learners and engineering, it is anticipated that students will be motivated to consider careers in engineering as a whole similar to the experiences students have when “playing doctor” or discussing what they want to be when they “grow up.”

Although only three challenges are cited in this paper, the authors recognize that there will be numerous other challenges which must be addressed in the future. Therefore, the implementation of specific strategies for systematically infusing career imprinting into PK-12 classrooms will be the focus of future publications.

Conclusion

The opportunities for PK-12 students to be exposed to engineering and its benefits to the world in general and to each individual in particular are infinite. Through strategic planning and the creation of real-world connections, students can be inspired to consider engineering as a “normal” part of everyday living which provides a pathway for the development of creative ideas that can impact the world in both positive and negative ways. Through “career imprinting,” PK-12 students can be encouraged to fully connect learning and living so they more intimately understand why what they are learning really matters. They will then, hopefully, choose to become engineers who are committed to making the world a better place to live, work, and play now as well as for future generations to come.

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