Addressing the Challenges of Preparing Science Teachers to Introduce Engineering to Early Learners in Elementary and Middle Schools

Tatiana V. Goris
Purdue University
tgoris@purdue.edu

E. Shirl Donaldson
The University of Texas at Tyler
Sdonaldson@uttyler.edu

Abstract

Students are usually introduced to engineering in middle school and occasionally as early as elementary school. The way of introducing to engineering fields at certain ages is critically important. The educational backgrounds of teachers assigned to teach introductory engineering material is essential to the success of the early learners. Quite often K-12 schools do not have enough instructors with engineering/technology postsecondary degrees. Thus, science teachers are forced to present engineering material, without clearly understanding engineering, or what to do with the concepts in the classroom setting. This paper presents some thoughts and concerns that been offered during the professional development workshop (sponsored by the State of Indiana Department of Education, MSP grant) for science teachers who are require to teach engineering fields in the 5-6 grades. In this case, the findings may be generalizable enough to address similarly applicable to older students. The authors argued, that foggy early introduction and weak foundation may hinder adult learners coming to study engineering at postsecondary level.

Introduction

The first introduction to engineering oriented on young learners is critically important. First attempts of presenting engineering will significantly impact the future interest of young students to learn more about it, or maybe even to devote themselves pursuing a career engineering or technology fields.

The authors strongly believe that introduction into engineering in college or even at high school levels is too late. In many states, public middle or even elementary schools make serious efforts to teach engineering to address this concern. An absence of qualified teachers with an engineering background creates severe problems for many of forward thinking schools. Frequently, science teachers are in charge of presenting engineering to students. Majority highly qualified science teachers still have ambiguity about differences between science and engineering, as well as what methods should be presented in the classroom to create student interest in engineering. This statement was confirmed all over again during the professional development workshop for science teachers sponsored by the Indiana Department of Education in January 2016.

Our conversation with teachers during this workshop outlined many interesting topics that might be applicable and attention grabbing for the majority of engineering and science teachers. We made an attempt to explain in an understandable manner:

- What engineering is;
- Overview of the three-century history of American engineering education;
- Discuss the current state of advanced manufacturing in USA, since this field is inseparable from engineering;
- Last, but not least, to point out the importance of detecting student misconceptions about scientific and engineering concepts. Majority of misconceptions are created in very young (elementary-school) age, and then are carried through the college and sometimes entire professional career [1]. This paper is organized as a review of discussed topics that inspire sincere interest of teachers through the recent professional workshop.

What is Engineering

This is the first question that a science teacher must answer. The next question is: how engineering is different from science? Without a clear understanding of similarities and differences in these two fields, further progression would be difficult. We recommended the perspective, that engineering brings about a solution of a particular problem in particular settings. Thus, to some point, an engineer is not just a professional specialist in a specific field, often an engineer may carry many roles, such as: scientist, manager, supervisor, and the first responsible person if something goes wrong.

A conversation about different engineering fields, such as civil, mechanical, electrical, food production, biomedical, and computer, is a useful approach to present the broad career orientation to young learners. In the USA, to become an engineer, a student has to satisfy two main requirements: first, to graduate from the institution of higher education, which is accredited by the American Board of Engineering and Technology (ABET), and if desired, to obtain Professional License.

Engineering Education in USA

In any country, Engineering Education is developed in specific historical circumstances, which are different from other regions. In this section we attempted to describe briefly almost 300 years of history of American engineering education. The authors believed that this informative piece should be presented to teachers and to students, adapted to the certain ages.

In the United States, Engineering began with the military [2]. George Washington appointed the first engineer officers of the Army in 1775, during the American Revolution. The interesting point is that there was no way to educate engineers. The Army established the Corps of Engineers as a separate permanent branch in 1802, and gave engineers responsibility for founding and operating the U.S. Military Academy at West Point. In the 19^{th} Century, U.S. growth drove the need for engineers. Most

American Engineers in those times started as apprentices on canal and railroad projects. Only a few classes (e.g. surveying) were taken to supplement this experience.

The number of the U.S. universities started to grow in the second half of the 19^{th} century. Some schools started following the French Model, such as ‘Polytechnic Engineering’. But Engineering was apart from the university. This situation had been changed with the Morrill Act of 1862, where Engineering became officially recognized and included into curriculum and degree programs. Some of the oldest American Engineering Schools that have become first tier research institutions include: Purdue University, Michigan State University, Penn State University, and Virginia Tech. In tandem, to address a separate political agenda, many Historically Black Colleges and Universities (HBCU) were founded after the second Morrill Act of 1890. HBCU’s educated the descendants of former slaves in arts, sciences, agriculture, technology and engineering [3].

From this time, the balance of theory and practice (shop & classroom experience) evolved. The shop dominated in early Engineering programs. In the beginning of twentieth century the classroom settings began to prevail, but progress was very slow. The establishment of the American Society for Engineering Education in 1893 signified the shift. As the discipline shifted the shop transitioned to modern day laboratories.

After the First World War, the Europeans brought their ideas and prospective into engineering education in the USA. As an example, European leaders in mechanics and fluid dynamics brought complex mathematical analysis. A few critical important names, who made enormous change in American engineering education, include Stephon Timoshenko, Theodore von Kármán, and Harald Westergaard. Stephon Timoshenko (Russia), first worked at the University of Michigan (1927) and Stanford (1936) . He wrote mathematically based textbooks for the strength of materials, structural mechanics, and dynamics [4]. In 1930, Theodore von Kármán (Hungary) brought German based theoretical fluid dynamics [5] to California Tech. He later helped to found the Jet Propulsion Laboratory.

The Second World War was a big stimulus to Engineering Education, which re-evaluated racial and gender roles in Higher Education and Engineering Education. After the War, thousands of veterans returned to school. Development of radar and atomic weapons brought home the importance of technology. But all the credit was given to scientists only. The Cold-War and Sputnik encouraged federal military funding to support the renovation of more theoretically based engineering. From those times, status of engineers was compared to the status of scientists. In most institutions, engineering science was fully integrated into the classroom. A unique characteristic of this time is that the majority of engineering fields after WW2 were Cold-War driven. In the 1950’s, the Cold War drove the research funding as well. The Cold War created the space race and more interest in engineering. The universities paid a little attention to the needs of industry, and adjusted the curriculum to please government demands.

Engineering education in the 60’s and 70’s was dominated by science. There was an enormous nation-wide swinging leap in the engineering curriculum: from practice to science. Federal funding to universities was reduced due to recession. By the 1980's, hands-on skills and experience dropped terrifically. Lack of skills produced the shift back from science to practice. Significant changes in engineering education happened in 1990's. Universities attended more to industry concerns, causing an even greater shift away from science to the "hands-on" and applied work.

Current State of Advanced Manufacturing in the USA

In this section, we made an attempt to establish the connection between understandings of the direction in which engineering education moves, by understanding the current state of manufacturing in the USA. The majority of educators in engineering fields are agreed that we are preparing students for jobs, which do not yet exist. Thus, we have to predict what skills and experience students will need to competitively join future job markets. Thus, to inform teachers, who present engineering to the elementary/middle school students, about the current situation in industry is critically important.

According to the US Department of Labor, manufacturing in the USA is highly differentiated geographically. A majority of high-tech industries are formed in economic clusters located in, or around, metropolitan areas [6]. Figure 1 presents percentage of manufacturing jobs by region.

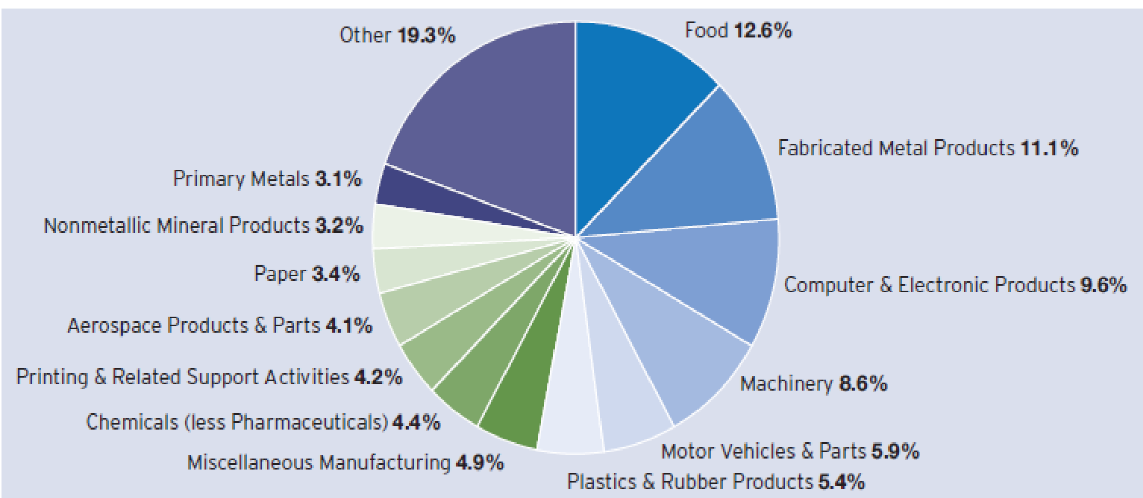

Figure 1. Industry Composition of Manufacturing Jobs

At the present time, one of the biggest nationwide challenges comes from the decreasing of domestic jobs and moving manufacturing oversees. According to the Bureau of Labor Statistics, the number of manufacturing occupations declined by 40.7 % from 1980 until the present [6]. Fast technological changes and increased international competition place the attention on the skills and preparation of the workforce, particularly the ability to adapt to changing technologies and shifting product demand … education becomes a continuous process.

Once again about Student Misconceptions…

This topic aroused a genuine interest from the participating teacher audience. In the present time, there is a large body of well-established research studies about misconceptions about natural events and science concepts. Misconceptions are defined as incorrect mental models, deeply rooted in everyday experience. They significantly affect learning, robust, and resistant to change [7]. Often high student grades do not guarantee the absence of misconceptions. And the most important point, e*ven teachers have them.* Earlier detection of misconceptions prevents from serious learning obstacles. The problem is that the majority of teachers are unaware of existing diagnostic methods for detecting and analysis of student misconceptions [8], [9].

Conclusion

After working with wide auditory of K-12 science educators that are in essence being forced to become early engineering educators, the authors continue to seek methods of support effective instruction. One suggestion is that science and math teachers work together to address misconceptions along with basics skills development that will be required for problem solving later.

A case could be made for more comprehensive professional development for these teachers and a specialization opportunity at critical points in their careers. This case is justified by the pipeline issues are visible at every juncture as millennials and the following generation hemorrhage from the STEM trajectory. New research is needed to determine which model would best address this shortfall.

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Biographies

TATIANA V. GORIS is a Clinical Assistant Professor at Purdue University, Columbus, IN. She teaches various courses in Mechanical and Electrical Engineering Technology. In 2012 Dr. Goris received her PhD in Technology from Purdue University. She also held BS and MS degrees in Electronics Engineering from Taganrog Institute of Technology, Russia. Her research interests emphasized on cognitive aspects of learning in Engineering and Technology Education, as well as Workforce development for advanced manufacturing.

E. SHIRL DONALDSON is an Assistant Professor at the University of Texas at Tyler in the College of Business and Technology. She teaches technology courses and provides faculty mentorship on industry sponsored projects. Professor Donaldson is a certified project management professional (PMP). A strong advocate of inclusionary practices in education and business, Dr. Donaldson encourages students to work to their strengths while constantly expanding their skill sets and prospective of life In 2015 Dr. Donaldson was selected to become an Entrepreneurial Leadership Academy Fellow. The Entrepreneurial Leadership Academy is a resource support program for faculty who have entrepreneurial interests.