TRANSFORMING ENGINEERING EDUCATION FOR THE 21ST CENTURY

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Abstract

This presentation will address questions like: What are the economic, social and technological challenges of today? What is the status of higher education today? Why do we need to innovate engineering/STEM education? What are the competencies needed to address the challenges and opportunities of the 21st century? How can we address those needs and innovate the curriculum and the learning experiences to better serve society and prepare engineers? University-wide and engineering education/STEM suggestions are presented.

Keywords: Engineering education; curriculum innovation; 21st century challenges

Introduction

Education is a fundamental right of every person, key to other human rights and the heart of all development. Education is the essential prerequisite for equality, dignity, and lasting peace. It is essential for the development of both individuals and nations, playing a key role in helping to solve complex problems and a means to re-establish stability and normalcy in systems destabilized by crisis. In its general definition, education can be defined as the development of knowledge, skills, and attitudes/values not necessarily related to one's job. Its general purposes are intellectual development, transmission of culture, citizenship, higher education and employment [1].

> *"Engineers create solutions for the welfare of humanity and the needs of society"* – Dan Mote, President US National Academy of Engineering

Thus, engineering education plays a fundamental role in developing and sustaining economic growth and in promoting society's well-being. It all starts with a well-prepared human capital, an engineer who possesses the competencies and professional skills needed to address the challenges and opportunities the 21st century world presents. It is imperative that engineering (and related STEM disciplines) engage in a process of continuous innovation and transformation to better address local, regional and global challenges and opportunities and better serve society.

The World Today

We all know that the world today is full of social, economic and political problems but also of many opportunities. Upon graduation, engineering students will be facing a "VUCA" world[1] – volatile, uncertain, complex and ambiguous, not the well-organized, predictable academic world. The world they will be facing is in continuous connectivity, movement of people who with their skills are enhancing innovation and new opportunities. This has prompted the growth of the knowledge era - where knowledge & ideas are the principal source of economic & social development (more important than capital, land, labor & other tangible resources) and where new ways of doing work & making business require a new kind of talent, with new and different competencies.

The World Bank Institute states in a 2007 report that *"whatever their development level, all countries must consider an economic model based on knowledge & innovation."* [2].

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We can see that countries that have followed the foundational elements of knowledge-based economies have become very competetive as the following graph from the 2017 WEF World Competitivenesss Report [3] demonstrates:

This is the top 30 of the 2017–2018 report:[10]

1.	Switzerland 5.86 (—)	11.	Norway 5.40 (—)	21.	Australia 5.19 (+1)
2.	United States 5.85 (+1)	12.	Denmark 5.39 (—)	22.	France 5.18 (−1)
3.	Singapore 5.71 (−1)	13.	New Zealand 5.37 (—)	23.	Malaysia 5.17 (+2)
4.	Netherlands 5.66 (—)	14.	Canada 5.35 (+1)	24.	Ireland 5.16 (−1)
5.	Germany 5.65 (—)	15.	Taiwan 5.33 (−1)	25.	Qatar 5.11 (−7)
6.	Hong Kong 5.53 (+3)	16.	Israel 5.31 (+8)	26.	South Korea 5.07 (—)
7.	Sweden 5.52 (−1)	17.	United Arab Emirates 5.30 (−1)	27.	China 5.00 (+1)
8.	United Kingdom 5.51 (−1)	18.	Austria 5.25 (+1)	28.	Iceland 4.99 (−1)
9.	Japan 5.49 (−1)	19.	Luxembourg 5.23 (+1)	29.	Estonia 4.85 (+1)
10.	Finland 5.49 (—)	20.	Belgium 5.23 (−3)	30.	Saudi Arabia 4.83 (−1)

Latin America has still to show in this first 30 list.

The world today also faces many of challenges- energy and water resources, climate change, cyber-attacks, education, to name a few. These challenges are multidisciplinary and will take multiple stakeholders to solve and the development of frontier technologies to provide solutions to global challenges.

Finally, the world today is entering the fourth industrial revolution, which will change not only manufacturing operations worldwide, but peoples' lives. The human factor for the 4th industrial revolution will be expected to [5]:
- Manage machines.
- Coordinate networks.
- Implement analytics.
- Identify process improvements.
- Implement changes.

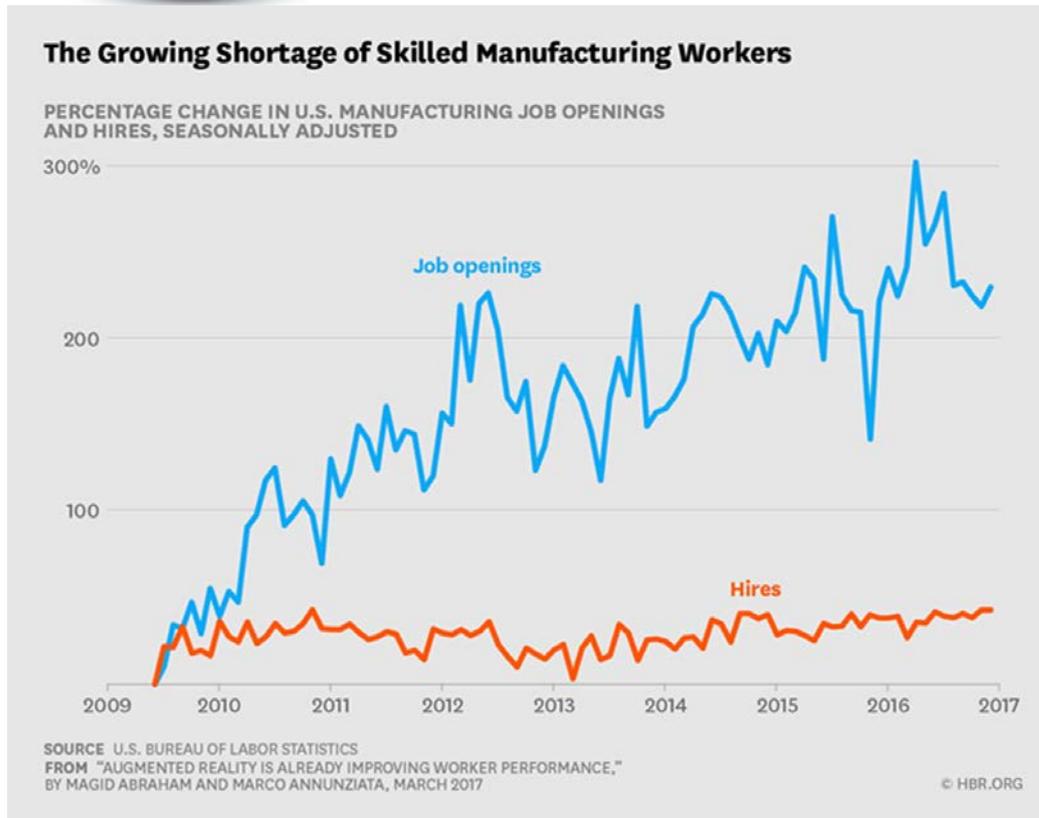Engineers and technical talent will have to deal with other kinds of systems and will require [4]:

- Adaptability in an uncertain world
- Analytics to make decisions
- Training the workforce for adaptability and aligning training with needs

This huge gap in competencies have been acknowledged worldwide.

"The need for skilled workers is pulling England down" [6]

"The largest skills shortage nationwide is for soft skills, with employers running up against a shortage of 1.4 million professionals." – Nina McQueen, LinkedIn, 2018

The following graphic from the US Bureau of Statistics (2017) shows the huge gap between hires and manufacturing jobs available in the United States:

The Growing Shortage of Skilled Manufacturing Workers

PERCENTAGE CHANGE IN U.S. MANUFACTURING JOB OPENINGS AND HIRES, SEASONALLY ADJUSTED

SOURCE U.S. BUREAU OF LABOR STATISTICS
FROM "AUGMENTED REALITY IS ALREADY IMPROVING WORKER PERFORMANCE,"
BY MAGID ABRAHAM AND MARCO ANNUNZIATA, MARCH 2017

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We can easily conclude that the skillsets engineers and other professionals needed in the 20th century are simply not adequate today.

The University Today
What has happened to universities? How are universities responding to these challenges? Well, it seems, that universities are teaching 21st century students with 20th century curricula in 18th century classrooms. Universities have remained mostly unchanged through most of the 20th century and today. I believe that universities have forgotten our role in society and become very selfish: institutional prestige, investigators self-advancement, competition, the need for external funding and many other "survival" drivers have encased the university in an inward-looking self-serving stance rather than one that looks on serving society first.

Why has this happened? I think the following quote says it all:

> *"In the spirit of honoring traditions, universities hang on to past practices imperiling their future."* – Clayton Christensen, Harvard University

And 96 percent of the university provosts (academic vice presidents) surveyed believed their universities were successfully preparing young people for the workplace, while only 14 percent of recent graduates felt they were adequately prepared for the job. [7]

The result of this enormous gap in perception is that recent graduates are unemployable because they lack the essential competencies (beyond knowledge) to deal with the requirements and demands of the job market of the 21st century.

Suggestions on How Universities Can Address 21st Century Needs
What can be done to address the challenges and opportunities of the 21st century? How can engineering colleges do to educate a new breed of engineer, one that is locally relevant but globally competent?

Well, we need to design a system that works!

Some university/college-wide ideas:

1. Re-visit & balance the mission of the university to serve society (educate, create, serve)
2. Innovate the curriculum AND the learning experience (competency/need based, backwards design, stakeholder involvement) and focus on learning (not on teaching) [1]
3. Develop an R&D + I + e portfolio (local & global areas)
4. Develop a culture of innovation across the university to be a model to society (CQI, international accreditation)
5. Reconsider the "business model" (inclusive, international, efficient, effective, accessible, affordable $i^2e^2a^2$)

Some specific ideas:

1. Design/transform the curriculum to an outcome/competency-based curriculum, starting from the graduate engineering competencies (knowledge, skills and attitudes/values). Which competencies? Those that are needed in the workplace, those identified by engineering accreditation agencies [8] [9] [10] [11].
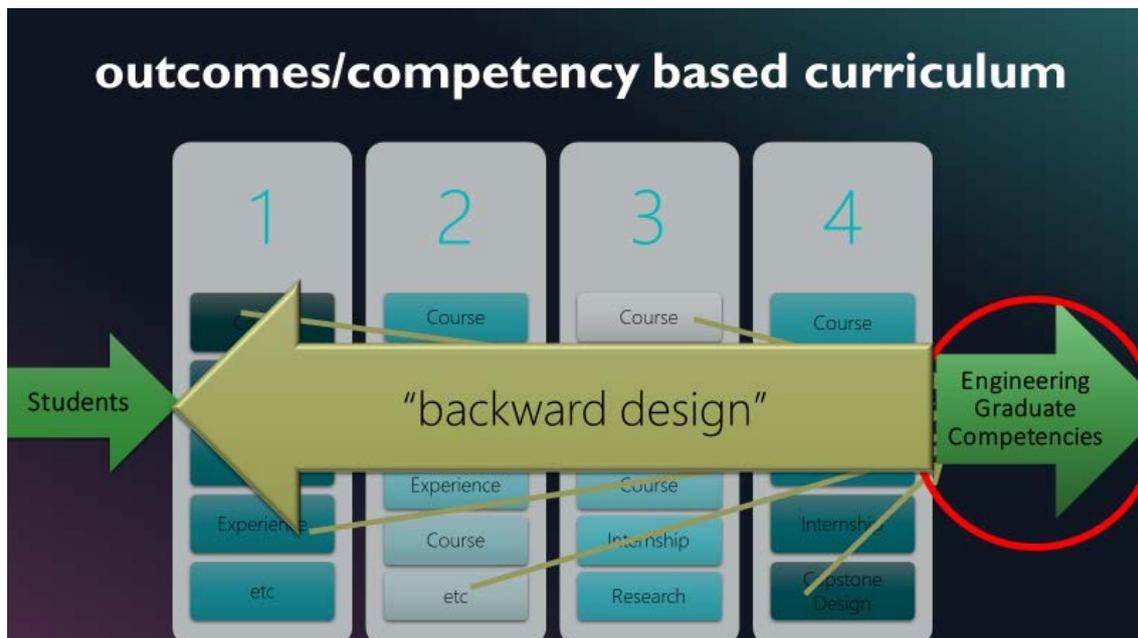
2. Integrate Active and Authentic Learning in the Learning Experiences. These:
   a. Promote and motivate learning
   b. Bring real-life into the classroom
   c. Develop engineering competencies

And research shows both increase learning and have significantly more impact on women than on men (when women have connections with their environment they feel valued).

3. Integrate the Global Challenges Scholars Program [12] into the learning experiences and develop competencies needed to address the engineering grand challenges of the 21st century. These are ambitious goals that will require a new generation of engineers, scientists, social scientists, politicians and artists who will collectively work to:

a. Create new capabilities
b. Provide pragmatic solutions for basic human needs
c. Develop new entrepreneurial opportunities
d. Reinvent human interactions
e. Transform systems thinking
f. Be the architects of a sustainable society
g. Be mindful of unintended consequences
h. Connect technology with society
i. Interact with non-engineering partners
j. Design and implement context-sensitive solutions

4. Develop engineering leaders throughout the curriculum and learning experiences. Programs like the US MIT Gordon Engineering Leadership Program and Beihang University in China are excellent benchmarks
5. Use data analytics in day to day operations and to achieve intended outcomes and improvements [13]. To answer questions like: What really works? Is it a commitment to new talent, technologies, or operating models? What curriculum areas we need to develop?
6. Increase gender and underrepresented groups parity.
7. Educate the engineering professor to become a change agent in the classroom focused on student learning not on teaching. Obtaining an internationally recognized pedagogical academic title, like the one provided by InnovaHiEd [14][15] which leads to the IGIP Ing.Paed title [16] may be an option.

Conclusions

If universities and schools of engineering want to serve societies better as they face the multifaceted problems and opportunities of the world today, they need to systemically rethink their 'business models'. Engineering schools need to navigate through a difficult task to develop new or innovate/reform curricula and learning experiences. This presentation/paper outlines some of the challenges and opportunities at a large and specific scales that can be undertaken.

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