Reimagining Engineering Education: Does Industry 4.0 need Education 4.0?

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Dr. Kleinke has over 25 years of industry experience in the design and development of electro-mechanical systems. As a tenure-track faculty member and Chair of the University of Detroit Mercy Mechanical Engineering department, he has developed a program of instruction that promotes student-lead design of assistive technology products for people with disabilities. The guiding principle is that student project work is more meaningful and fulfilling when students have the opportunity to experience interaction with real live "customers." Dr. Kleinke is currently the Director of the Graduate Engineering Professional Programs, emphasizing Systems Engineering and Graduate Product Development programs.

In addition to academic work, Dr Kleinke continues his involvement in industry as he conducts seminars on innovation which are tailored to the needs of industrial product companies. Dr Kleinke's work with the Detroit-based technology hub, Automation Alley, is engaging academia in the dissemination of Industry 4.0 knowledge to support the regional industrial ecosystem.

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Abstract

Industry 4.0 is a commonly used term to refer to the fourth industrial revolution that is currently underway. The hallmark of this transformation is the effect of digital technologies

faster and more efficiently.   College professors

What is Education 4.0?

There is really no formal definition of Education 4.0. Thought leaders have identified characteristics of Education 4.0 and there has been a lot of discussion on how it ought to be different from the current model of education. In the current system, engineering programs receive raw materials, I.e. students graduating from high schools aspiring to get a college degree. In college, particularly in engineering, students primarily follow a prescribed curriculum in a format that is largely traditional, classroom-based instruction. The curriculum is prescribed by external entities such as universities, programs, accreditation agencies such as ABET, and professors; this means the students are required to learn materials that “others” prescribe. It has to be done as per a set schedule, i.e. in prescribed time blocks, semesters or quarters, and following a prescribed prerequisite structure. After finishing four years of curriculum students graduate and join the workforce. Current education paradigm uses the “Empty Container Paradigm.” It is assumed students will start a given course knowing nothing about the topic and while they are enrolled in it knowledge will be poured

Complex problem Solving		Literacy	Good Communication skills
Critical thinking		Numeracy	Physical and Engineering Sciences Fundamentals
Creativity	Foundational Literacies	Scientific Literacy	Ability to Identify formulate and solve engineering problems
People management		Information and Communication Literacy	Systems Integration
Coordinating with others		Financial Literacy	Curiosity and Persistent Desire for Continuous Learning

This report built on prior studies such as the National Academy of Engineering studies: *The Engineer of 2020* (Parts I and II) (2004, 2005), *Engineering Research and America's Future* (2005), and the National Academies study, *Rising Above the Gathering Storm* (2005). It is quite interesting to note that some of the skills that are being emphasized now were listed in these earlier reports as critical necessities. Duderstadt's recommendations included some large-scale changes involving government, academia and industry partners to re-vamp the engineering education ecosystem of the nation. Needless to say, most of that has not happened. All the evidence just goes to show that the needs assessment is reliable and have strong support among the peer community.

In the European Union (EU) a project was undertaken on this same issue called *The Universities of the Future (UoF)* project that aimed at identifying the educational needs arising from Industry 4.0 in Europe. Funded by the EU, this report identifies the skills required for succeeding in the Industry 4.0 environment. In this report, the authors reviewed all current relevant publications and developed a list of technical and soft-skill competencies needed to be successful and productive in Industry 4.0. The list of soft skills is similar to the other competencies shared above. In Table II we list all the identified technical competencies separated as engineering, business and design competencies.

Table II: Engineering, Business and Design Elements of Industry 4.0

Engineering Competencies	**Business Competencies**	**Design Competencies**
Data Science and advanced (Big Data) analysis	Technology awareness	Understanding the impact of technology
Novel human-machine interfaces	Change management and strategy	Human-robot interaction and user interfaces
Digital-to-physical transfer technologies, such as 3D printing	Novel talent management strategies	Tech-enabled product and service design
Advanced simulation and virtual plant modeling	Organizational structures and knowledge	

Characteristics of Education 4.0 (Fisk)

1. **Diverse time and place:** students will need to learn at different times and different places, e-learning will be a critical part of the system. Concepts of flipped classrooms will have to be implemented more universally when students will learn the theory on their own and do hands-on applied work during in-person sessions.
2. **Personalized learning:** students should be able to learn at their own pace. The tools should be adaptive so that students with advanced capabilities can move faster and complete more difficult tasks while beginners can take time to master rudimentary skills before moving on. Students will need to receive positive reinforcements and encouragements so that they can move forward with confidence.
3. **Free choice: Learning styles of individuals vary, it is imperative that the students should be free to use their own combination of learning tools and methodology.** Students will learn with different devices, different programs and techniques based on their own preference, such as blended learning, flipped classrooms and BYOD (Bring Your Own Device), etc.
4. **Project based:** Learning will need to be project based and replicate the real-world as closely as possible. They should be able to apply their skills in a variety of situations, including skills such as organization, teamwork, time and project management, etc.
5. **Field experience:** experience in the job will be even more important so education

2. **Student-driven:** The education system needs to enable and support the self-organizing capacity of our students. Students should be defining their own study goals. Autonomy (self-organization), purpose and mastery are the fundamental elements of intrinsic motivation.
3. **Interdisciplinary:** Our future challenges are increasingly interdisciplinary and transdisciplinary. This means that a stable and well-defined range of subjects is becoming obsolete. We need to provide a structural overview in their field of study that will enable them to integrate the knowledge they are constantly acquiring. It will be our job to

Figure 1 captures all the characteristics discussed

4. The pool of K-12 prospects is dwindling due to population demographics and lower interest in traditional education programs.
5. Interest in Industry is being overshadowed by concerns for the environment, the promise of e-business, Apps, etc.
6.

- “Assessment poses a big challenge. ABET may need to be involved.”
- “Faculty will feel at a loss grading reflection, and a lack of clear expectations will cause students to fret.”
- “Moreover, engineering faculty cannot control general education requirements.”
- “Freshmen, it was noted, are ill-prepared for open-ended projects.”
- “Co-curricular activities detract from time devoted to academic activities—and how do you grade them?”
- “When you ask me to do more, I have to do less somewhere else . . . my class is too large . . . Why are we doing this; it’s not our responsibility . . . there’s no budget for it.”
- “The reason our colleagues don’t do active learning is that they’re scared of being in a student-centered environment where they don’t dknw

Recent efforts in Engineering Education reform and case studies

While the paradigm of engineering education has remained broadly the same for many years, changes have been happening in many aspects of programs. These changes include mandatory co-ops or internships, industry-sponsored and industry-directed projects, mentorships, undergraduate research, on-line learning, flipped classrooms, and many others.

2. A move towards socially relevant and outward-facing engineering curricula that emphasizes student choice, multidisciplinary learning and societal impact, coupled with a breadth of student experience outside the classroom, outside traditional engineering disciplines and across the world. Although these types of activities can be found in many

Reward and recognition of teaching	Tenure and Promotion system mirrors that of R1 universities in the US and is primarily dictated by r

Teaching and learning support	Teaching and learning support and training is provided both through the central IEP and through the College. Also the University has several programs such as UCL Arena and UCL: Changemaker that supports teaching and learning and collaborations in these areas.
Reward and recognition of teaching	Career tracks are divided into an academic track, an education-focused track and a research track. University instituted reform to develop a process for improving and formalizing the recognition and reward of teaching achieveme

	of study, students must an area of engineering and complete a branch of the *topic tree* corresponding to that field.
Interdisciplinary opportunities	Zero interdisciplinary opportunity at the curriculum level. During on-campus and off-campus students get a chance to interact with communities and professionals within and outside of engineering.
Pedagogical approach	

	the university's control. The goal is to apply engineering to real-world problems. • **a pioneering approach to blended and online learning:** the university is having a growing strength in on-line learning that is impacting positively on-campus and off-campus.
Student Selection	Until recently all selection was determined by a process set up by the Dutch government. Overprescribed programs in high demand has been recently allowed to set their own criteria for enrollment. So, Aerospace Engineering is one of the first TU Delft programs to introduce student selection procedure. Prospective Aero.E.. students will be selected using a four-stage process: completion of the *Introduction to Aeronautical Engineering* mini

time will require a paradigm shift in the education ecosystem that has operated the same way for over a hundred years and is also a system where change comes very slowly. It seems that the biggest challenge will be to develop a paradigm of education that will deliver the desired service at a scale that is needed. The four cases summarized in the paper have been successful in implementing some aspects of this quite successfully: SUTD in the area of breaking down disciplinary silos and including hands-on education throughout the curriculum, UCL in the area

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