Bridging the Skills Gap in STEM Industries

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INTRODUCTION

The skills and knowledge that engineering students have acquired by the time they graduate play an important role in their employability and ultimately their success. Several discussions in recent years have focused on an apparent gap between the skills in demand in industry and those supplied by education [1]. To maintain a healthy flow of new graduates into industry, a systematic approach is required to ensure that the education students receive at universities meets the criteria for engineering in Europe as set out by EUR-ACE® system [15] as well as the local needs of industry in each country.

In September 2013, MathWorks and YouGov surveyed [2] more than 300 employers across the UK and 24 of the country's leading Russell Group academics involved in teaching science, technology, engineering, and mathematics (STEM) subjects. The objective of the research was to highlight the effect of a growing skills gap in the (STEM) industries, help identify its causes, and discuss possible solutions.

Section 1 of this paper outlines the relevant results of the survey. Section 2 covers some of the practical steps taken to mitigate the influence of this skills gap, citing evidence from existing programs. Section 3 summarizes the conclusions.

1 STEM SKILLS GAP SURVEY RESULTS

The survey conducted by YouGov in conjunction with MathWorks provides insight into the ways universities and industry view their roles in the development and support of new graduates of STEM subjects in the UK and their assimilation into the workforce.

1.1 Primary findings

An analysis of the survey responses revealed the following:

- A majority of respondents agreed that a gap exists between the expectations of employers and the knowledge and skills of new graduates. Of those surveyed, 59% of businesses and 79% of academics surveyed believe that there aren't enough skilled graduates to address the needs of the society.
- Universities and industry believe that this gap can be bridged through cooperation between the stakeholders. 52% of the employers and 64% of academics think that industry does not contribute sufficiently to the process at present. Interestingly, 63% of the companies think they

should have a greater say while 46% of universities welcome such interaction. Of the academics who would like greater involvement of industry in curricula, all expect workplace experience and internships to be an effective strategy. Moreover, 61% of businesses and 68% of universities are convinced that bridging the gap will take at least a decade.

- Around half (51% of employers and 53% of academics) believe that UK has to invest more in STEM education.

1.2 Employer Expectations

Employers are finding it progressively more difficult to find and employ engineering graduates who are able to hit the ground running with minimal retraining. To quote from [2]:

"It's becoming increasingly difficult to find graduates to enter the profession, and particularly hard to recruit graduates with the key skills required to make an immediate impact as part of our workforce. Part of the reason for this may be the way universities now approach teaching. Graduates have domain-specific skills but seem to lack the appreciation that those skills are transferrable. This is leading to a 'skills silo' and thinking in 'one direction.'"

–Senior manager, STEM graduate employer

The main areas in which industry needs to train the recent graduates during the first 18 months of their employment are technical skills, communication skills, business and commercial awareness, IT skills, team working, and self-management [3].

Indeed, some employers have started defining master's degree programs [4] along with a number of universities to address the skills they require in their workforce.

Another employer highlighted the need for better alignment between industry needs and university curricula [2]:

"The requirements of industry aren't necessarily aligned with university curricula. My impression is that UK graduates favour a deeper, less broad knowledge; while other EU countries seem to be better at producing graduates able to think in a wider way. Closer alignment between industry and academia is important because not all companies want or need deep knowledge, especially at the cost of wider engineering skills."

–Manager, employer of STEM graduates

2 PRACTICAL STEPS TO BRIDGE THE GAP

The survey results underscore the need for a joint effort between industry and academia to bridge the gap between employer expectations and graduates' skills. Beyond this immediate need, proposed solutions should also address the steady decline in the number of students studying STEM subjects.

A number of practical steps to address these needs are outlined below. These are the results of several years of collaboration between universities and industry.

2.1 Implementing Project-Based Learning

Project-based learning is one of the key approaches used by universities to make better use of teaching resources and facilities available at educational establishments. In this paradigm, projects determine the subjects they learn. Instead of adhering strictly to one methodology universities have generally adopted a more pragmatic approach in which students learn by completing projects that solve authentic problems encountered in industry. This is complemented by customary didactic teaching methods. Although project-based learning is not identical to *problem*-based learning [12], the focus remains on the practical experience and self-direction of the learner.

Experiences of universities using project-based learning with Model-Based Design [6, 16] have revealed the following primary advantages:

- **Applications increased**; **withdrawals in mechatronics virtually eliminated:** While some schools are having difficulty attracting and retaining engineering students, a university using CDIO™ [5, 10] has managed to reverse this apparent trend. CDIO stands for Conceive, Design, Implement and Operate. It is a comprehensive program adopted by some universities in teaching engineering which brings a balance between engineering practice and disciplinary knowledge. At this institution where CDIO is used in their mechatronics degree course despite the high dropout rate in many fields, in mechatronics it is almost zero. CDIO with MATLAB® and Simulink® is a big part of that because the students are motivated and engaged in meaningful assignments.
- **Multidisciplinary projects simplified**: On multidisciplinary projects, students with quite different educational backgrounds report working together more easily because they are using the same tools.
- **Tight project deadlines met**: Students can move quickly from simple equations and theory to testing real implementations. They don't have to reinvent the wheel because available toolboxes provide many of the advanced algorithms they require. Automatic code generation provides further time savings.
- **Collaboration with industry partners streamlined**: Companies often provide models that help students jumpstart their work, and students deliver models that industry partners use for simulation or even code generation.
- **Hundreds of industry projects completed**: Graduate students work with engineers at some of the largest companies to design and implement hundreds of systems, including mobile phone antennas, mechatronic systems, and controls for a wide variety of industries.
- **Increased employment opportunities for graduating engineers**: Students in CDIO programs complete real projects with the tools engineers use in industry. As a result, graduates have practical skills and knowledge that are in high demand.

2.2 Supporting Research Programs

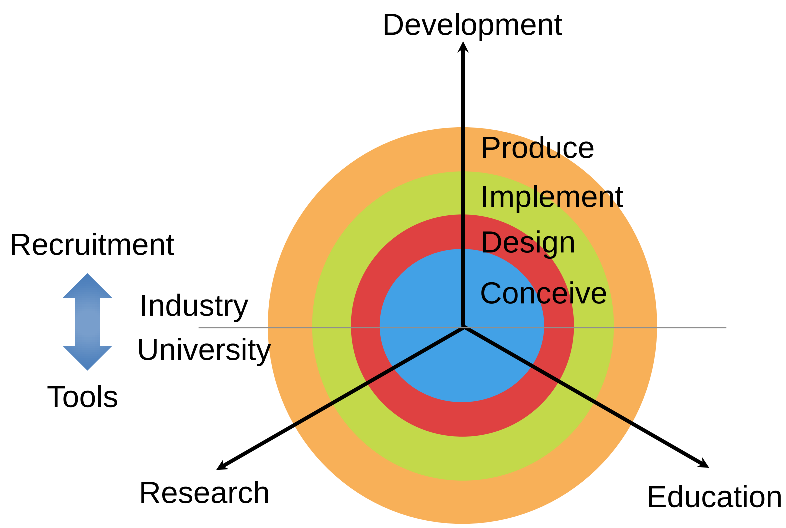


Fig.1 Industry-University Interaction – Research and Development

At universities, research ultimately drives technology and education. Fig.1 depicts some of the interactions between universities and industry. The various phases of development are:

- Conceive, in which the concept takes shape (also called incubation phase).
- Design, in which decisions about the technologies to be used are made.
- Implementation, in which appropriate tools (both hardware and software) are employed to execute the design process.
- Production, in which a new product is introduced into the marketplace.

Typically development is the domain of industry and research is seen as the arena of universities. However, much interaction can take place during each of these phases between research and development at universities and their industrial partners. Such healthy interaction greatly supports creation of a sustainable environment for innovation and progress.

Moreover, industrial partners often recruit researchers, facilitating greater levels of cooperation and technology transfer between institutions. Industry can support universities not just financially but also by providing appropriate tools and industry-proven methodologies.

2.3 Developing Curricula at Universities

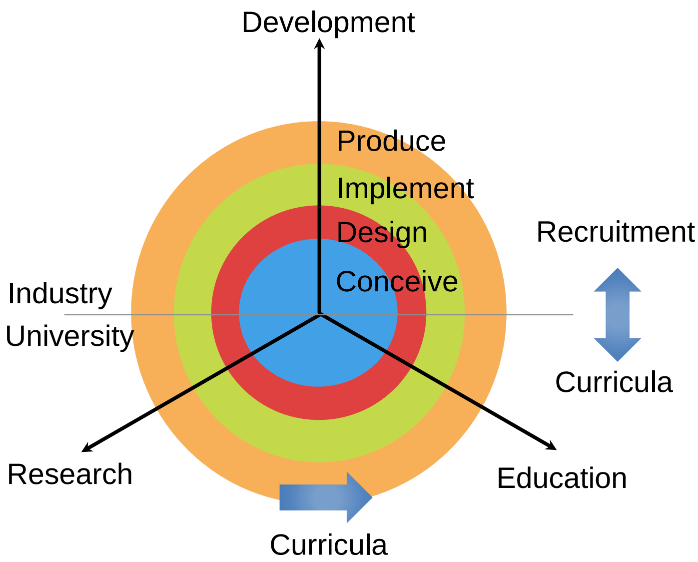


Fig.2 Industry-University Interaction – Curriculum Development

Another level of necessary interaction between universities and industry is through basic education and curriculum development. Engineering curriculum is essentially driven by two factors.

The first driver is the research interests of the academics. Much of what is taught at higher levels is taken from leading edge research in the institution. These subjects form the bedrock of future product development and tend to foster enthusiasm in the students to pursue the same research.

The second driver is the direct and indirect requirements of industry. Commercial organizations, as recruiters and recipients of the fruits of engineering education, have a duty to support and encourage new materials and methods in education.

For example [7], in teaching guidance, navigation, and control of an unmanned aerial vehicle to students, one academic institution collaborated with an industry partner to create a platform for developing Arduino-based autopilots programmed with Simulink models. There are several advantages to this approach, including:

- A focus on core concepts is maintained. Students do not spend too much time in developing C programs; instead the task is focused on building real flight control systems.
- The designs are verified through simulation before test, which reinforces the methodology adopted in industry.
- Real-world experience is acquired, providing an edge to students when they seek employment upon graduation.

Recently, more and more programs make use of CDIO in this context, both explicitly and implicitly [11].

2.4 Supporting Student Competitions

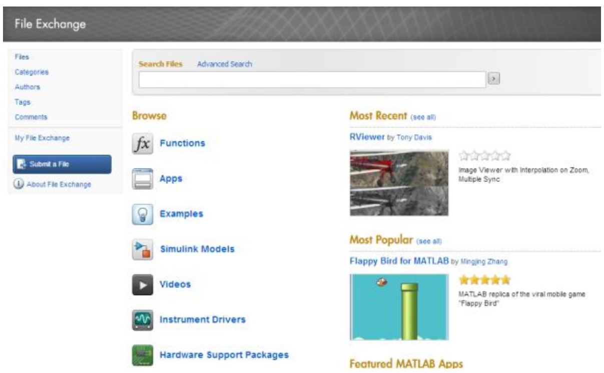
Student competitions provide a powerful platform for preparing engineering students for industry. The competitions are typically set up to provide students with realistic challenges. Although some have a simple well-defined objective others are open ended and give students more latitude. They generate a great deal of excitement among students, which leads to higher levels of engagement. Some key benefits for the students include:

- Acquiring a sense of accomplishment
- Experiencing innovation
- Developing life skills such as teamwork, time management, and project management
- Learning about the engineering design process with a practical, hands-on approach
- Making a difference to society

An example is the iGEM [8] competition for synthetic biology. In this competition, a team of students, who won the 2013 European jamboree, used extensive mathematical modeling to develop a sustainable system to reduce the damage that aphids cause to the agricultural industry. The team created a synthetic solution that reduces reliance on insecticides.

Another example is the Formula Student Germany engineering competition [14], in which 110 teams from 35 countries recently designed combustion and electric vehicles. They competed in categories such as manufacturing cost and engineering design as well as dynamic aspects such as acceleration and skidding. Teams focused on different aspects of the car with different approaches [13], resulting in a wide variety of methods, tools, and technology employed. Despite the competition scenario, the teams openly share what they do and how they work, leading to more innovations year after year.

2.5 Building Student Communities



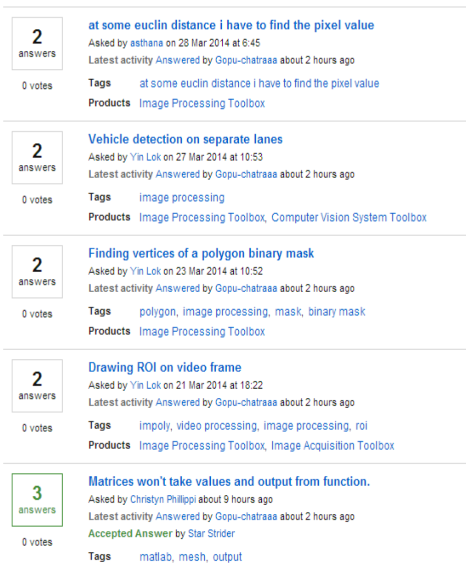


Fig.3 File Exchange - cooperative community example Fig.4 Q&A Environment (MATLAB Answers)

Students do much of their learning from each other, supplementing the instruction they receive directly from their teachers. It is therefore important to create and support an environment in which this informal cooperative learning can take place and be sustained.

Fig.3 and Fig.4 depict examples of an on-line system for exchanging applications and a simple environment for questions and answers in which contributors can interact with each other freely. The virtual community is global, and answers can come from anyone around the world. Such virtual environments also offer an opportunity for students to demonstrate their capabilities to potential future employers. Moreover, they provide students with a platform to interact with professionals and learn directly from them. In addition, students can quickly learn by building prototype solutions not from scratch but from an existing framework or example found on-line.

2.6 Learning through gamification

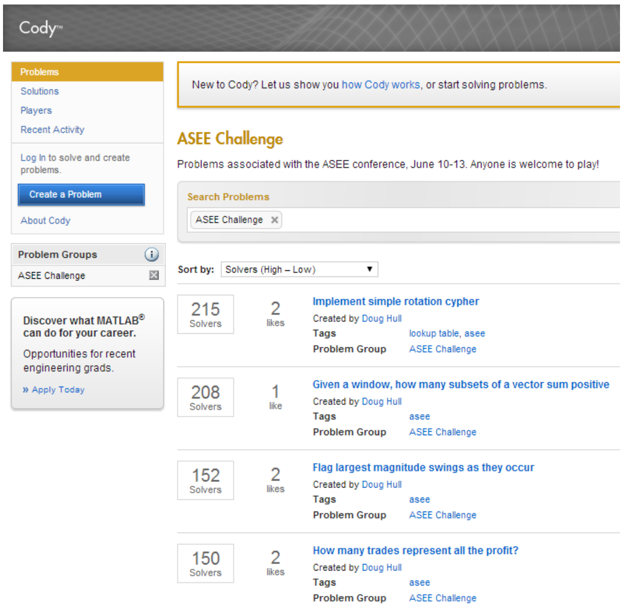


Fig.5 Cody - eLearning game example

Fig.6 Typical problem and statistics of solvers

Gamification of learning is a powerful method of keeping students engaged using both intrinsic and extrinsic influencers. There is nothing new in using games to help learning. Giving badges, medals and acknowledgement for achievement in projects or contests in schools and universities has been common place. Using these same approaches with the internet is what is largely new. One's preference is to employ largely intrinsic influencers such as status and badges of achievement instead of extrinsic ones such as T-shirts and monetary awards.

Environments such as MathWorks Cody™ are one such example to enable students to solve challenges set by others and also set their own challenges.

The competitive, cooperative environment helps in building a community whose players learn together. The primary aim is to sharpen the students' abilities, develop better problem solving skills, and enable them to learn from the successful solutions and mistakes of others.

2.7 Establishing a platform for continuous dialog

It is in the best interests of employers in industry to be party to a continuous dialog with the educational establishment to build a regular, systematic approach of consultation, action, and reflection. Greater cooperation between industry and academia will enable more effective approaches to be identified compared to the hands-off style that has been by adopted by much of the industry at present. A sustainable approach to reforming the way industry interacts with universities is required – not just a client-server relationship.

3 CONCLUSIONS

Success in education depends on several factors, including:

- Pedagogical effectiveness
- Standards and requirements of engineering institutions
- Expectations of employers

We have shown that collaboration between universities and industry can take different forms. Moreover, the collaborative efforts can be complementary for achieving the objectives of academic institutions.

The examples cited here are only a few approaches of the many currently in use in different countries. Individual institutions could combine suitable strategies from multiple institutions to bridge the STEM education gap. Truly effective methods will also need to address secondary education—a discussion that is beyond the scope of this paper.

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