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A SHIFT IN FOCUS IN ENGINEERING EDUCATION: TAKING INTO ACCOUNT THE EXPANDING ROLES OF ENGINEERS

Aruna SHEKAR and Sangeeta KARMOKAR
Massey University
Auckland University of Technology

ABSTRACT
Historically, engineering educators have focused mainly on technical competencies, but now there is a shift in focus to include much broader areas of social, economic, ethical and environmental dimensions. The role of engineers in society is expanding to include a consideration of both technical and less-technical areas, and significant issues such as the impact of their solutions and their maintainability. The present role and perception of design in the engineering curriculum has improved markedly in recent years. Practitioners and academics are making constant efforts to include more design in engineering by including design thinking, systems thinking and systems design methods. The engineering curriculum has a strong foundation of science and mathematics, analytical and convergent thinking. Design brings in divergent and lateral thinking. Combining the two forms of thinking provides a balanced approach to problem solving. Taking this approach further, how do we extend this to the wider community? The Triple Helix model (Figure 1) is increasingly seen as a catalyst to adding value to projects in the form of social, cultural, environmental or economic returns. Increased prominence has been given to the role of universities in stimulating economic growth through industry related research, technology commercialisation and high-tech spin-offs but it is not always easy for universities to accommodate these changes. So, how do we incorporate the value of community, government and industry and blend them into engineering education? This paper draws on existing literature related to hybrid education to focus on developing an education system that cuts across both organisational and disciplinary boundaries. Finally, the paper lists some of the open research questions that must be answered to identify best pedagogical practices of improving engineering through triple helix model.

Keywords: Engineering Education, Triple Helix Model, Product Design.

1 INTRODUCTION

Technology, design and creativity have always played a key role in the economy and rapidly moving towards a knowledge-based strategy for growth. There is an increasingly global society driven by the growth of new knowledge and joined together by rapidly evolving information and communication technologies. The implications of technology driven growth on engineering education is vital. The globalisation of markets requires engineers who are capable of working with and among different cultures and being knowledgeable about global markets [1]. The role of engineers is not only to improve the human condition through new technologies and innovation but also to enable the creation of new communities and social institutions more capable of addressing the needs of our ever-changing society. A new perspective is needed to educate engineers as the distinction between industry, society and the government is blurred. Ten years from now the employment scenario will be very different from today, so how do we prepare young engineers for that future?

In view of these changes in engineering and society, it is easy to understand why some raise concerns that we are attempting to educate 21st-century engineers with a 20th-century curriculum taught in 19th-century institutions [1]. There is a widespread need for entrepreneurship and creative practice within engineering curricula. A new paradigm of engineering education needs to accommodate a far more holistic approach to addressing social needs and priorities, economic, environmental, political considerations with technological design and innovation. One of the best ways practiced in business and product design to connect with government, educational institutes, or community partners is through a Triple Helix Model (Figure 1).

2 TRIPLE HELIX MODEL

This section first describes in brief Mode 1 and 2 roles of universities and the changing role in society. Then it leads to describing the Triple Helix model, with the caveat that “Industry” is considered instead to be “Enterprise” that includes a much broader scope of possible interaction.

2.1 Knowledge Space

The Triple Helix model [7] is a model that reflects the changes in a knowledge based economy and the new transformations in a modern university. A triple helix relationship between university, industry and government means an evolution of institutional relations. The Triple Helix model justifies a new configuration of the institutional forces within innovation systems with the opening up of companies traditionally closed to external partnerships. As knowledge has become an ever more important and crucial part of innovation, the university, as an institution for the generation and dissemination of new scientific and technological knowledge has a critical role in generating innovators and problem solvers.

According to [7], the evolutionary process in the Triple Helix model (Figure 1) involves a transition from the ‘statist’ stage in which government controls academia and industry, to the laissez-faire state relationship between the three institutional spheres; and finally to the hybrid stage in which each institutional sphere keeps its own distinctive characteristics and at the same time also assumes the role of the others. The evolutionary process underlying the Triple Helix system is graphically depicted in Figure 1 below. Each helix would be connected to another thus assisting in the formation of interfaces between them. Industry will gain some of the values of the university, sharing as well as protecting knowledge; research groups in industry would collaborate with public and university research groups to achieve common long-term strategic goals [6].

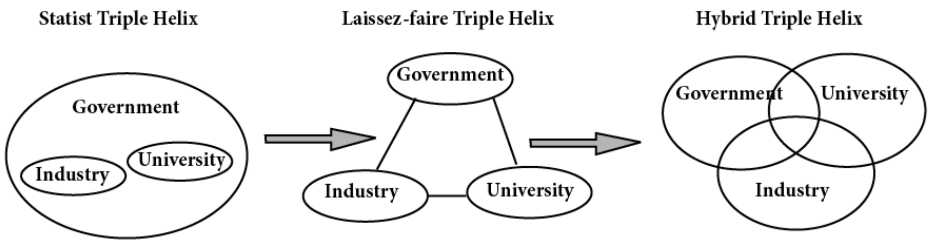

Figure 1. Hybrid Triple Helix Model [8]

Triple Helix model has been successfully integrated in product design and business design field. There are a few labs and research centers such as Design for Well Being (http://www.dhwlab.com/about/), Icehouse (https://www.theicehouse.co.nz/), Epicenter (http://epicenter.stanford.edu/) and Innovation Lab (https://www.tue.nl/en/innovation/) working with corporates, community and the local government.

2.2 Role of Education/ Universities

The fundamental purpose of many modern Universities has not changed significantly over the last centuries in terms of the provision of teaching and the conduct of research. Mode 1 knowledge production is characterized by the control of theoretical or experimental science; by an internally-driven taxonomy of disciplines; and by the autonomy of scientists and their host institutions. In contrast, ‘Mode 2’ knowledge production is socially distributed, application-oriented, transdisciplinary, and subject to multiple accountabilities [2, 3].

Under the traditional paradigm of ‘Mode 1’ there are clear tensions between the roles of the university in servicing the needs of local economies [4, 5]. Such separation is diminished by the emergence of ‘Mode 2’ production of knowledge. In conjunction with this shift to Mode 2 knowledge production, the Triple Helix [6] stance has emerged, which states that a university can play an enhanced role in innovation in increasingly knowledge-based societies. Existing relations between industry, government and the university persist, but to these models of action and learning is now added a supplementary layer of ‘knowledge development’. This is a layer in which specific groups inside academia, enterprise and the government collaborate in order to address emerging problems in a complex and changing economic, social and intellectual world.

Many Universities are extending their teaching and research capabilities from educating individuals in theory alone to shaping them in entrepreneurial practices and incubation programmes. They provide new teaching and research formats exemplified by inter-disciplinary centres and hybrid organisations such as science parks, academic spin-offs, incubators and venture capital firms [6]. However, such ventures tend not to exhibit some of the fundamental features associated with Mode 2 knowledge production, particularly the transient nature of the endeavor. The following section outlines the development of the initiative from its grounding in the Triple Helix model.

3 BROADER LEARNING IN ENGINEERING EDUCATION

Given the rapid change in global economy, engineers who are both innovative and entrepreneurial will be in high demand. As a result, entrepreneurship education has become one of the fastest growing areas in engineering education [9]. In the context of New Zealand, engineering education, courses and programs that deliver entrepreneurial skills, knowledge, and experiences to students are very diverse in terms of target audience and key objectives. Some entrepreneurship programs that primarily target engineering or science students are more like a technology entrepreneurs or engineering entrepreneurs. In engineering schools, entrepreneurship approach is embedded with in the engineering curriculum, while other is offered as elective or extra-curricular activities that may or may not be directly related to their core subjects. Breadth in engineering education is now as important as depth and specializations. This is because most real-life problems are not mono-disciplinary. They involve a combination of disciplines and perspectives. The modern engineer must be able to think and solve problems across technical and non-technical aspects. For example, student teams are taught to work together to solve a real-life problem such as developing a smart sensor for range-hoods (with industry partners) that can detect smoke from burning food. They must take into account safety issues, user behavior, standards to comply with, and technical aspects of material and functionality. These projects are part-funded by the government and supervised by Universiy staff.

To broaden student's entrepreneurial experience, initiatives such as Science, Technology, Engineering and Mathematics Tertiary Education Center (STEM-TEC), meet ups, makers space, SKUNK Day (A free day for students and staff to experiement with their project and research interest) and creative mornings organize seminars and workshops. These are extra-curricular activities and not considered as part of the core-engineering curriculum. It is organised in collaboration with students, creative communties, industries entrepreneurs and experts. These initiatives bring together business, government, researchers, students, and the wider community in New Zealand. Students need a little support to feel encouraged and equipped to engage in real-world problem solving, and to put extra time to be part of these activities. There are few government funded projects under Ministry of Business and Innovation (New Zealand) such Unlocking Curious Minds, and Catalyst Fund to support and encourage projects that benefit humans globally – such as improving sanitation, health, water and energy supplies. These needs and issues provide the motivation and drivers for engineering innovations. Students are engaged in real world projects through co-operative education. Projects are initiated by industry and provide the context within which creativity and problem solving can occur. Students are motivated as it is a real problem that they can relate to and the outputs have benefits for people.

There are numerous examples of application driven projects and research in engineering schools. However, they are mostly technology-based. There is no doubt that technology plays a major role in innovation as an enabler, but even more critical role in sustaining the economy and social well-being, engineering education is challenged to shift from traditional problem solving and design skills toward more innovative solutions embedded in a complex array of social, environmental, cultural and ethical issues. There are many practical challenges that need to be addressed for this major shift, discussed in the next section.

4 CHALLENGES AND RECOMMENDATIONS

Literature highlights the need for entrepreneurship and real business contexts in engineering education rather than entirely textbook examples. However, there are many practical challenges in engineering education to include the diverse roles and responsibilities of professional engineers. These include:

- It is often difficult to add more content or time to the existing engineering curriculum, and hence there are few options available.
- Entrepreneurship papers are mostly offered by different departments and not by the engineering department. So students assume that it is an optional subject and fail to consider it as an integral part of becoming an engineer [12].
- In engineering education, personal and interpersonal skills, such as teamwork and communication, are often called generic skills. More emphasis is generally placed on technical issues when compared to 'soft' skills, which are actually essential to engineering practice [13].
- With a diverse engineering faculty and staff, the perceptions of the value and place of personal and interpersonal skills are very different. Few are of the opinion that these skills are of secondary importance or that they should be taught separately from disciplinary content and may be unwilling or may not know how to integrate them into their courses.
- Learning to solve classroom problems, as a part of assessment does not necessarily prepare engineering students to solve workplace problems [11].
- One of the barriers to delivering entrepreneurship to students in engineering or the sciences is the time or space available for electives or any extracurricular activities.

To prepare students to become professional engineers, programs needs to provide an education that is better at supporting students in learning, not only disciplinary core content but also personal and interpersonal skills [10]. In the process of learning inter disciplinary content, it provides an experience a way to apply and express technical knowledge and transforming an abstract idea into working knowledge. The design of engineering education curriculum needs to mutually support disciplinary courses with an aim to integrate interpersonal and systems thinking skills. Entrepreneurship needs to be built and delivered as part of core engineering curriculum rather than an additional subject or an elective. It could be achieved through project-based courses within the curriculum. Collaborations across disciplines such as business, social sciences, and engineering help integrate this broader holistic engineering education. Projects that are government funded, initiated by industry and solved by university staff and students, are part of the answer and are growing in popularity. This three-way partnership brings benefits to all. University staff and students stay relevant to industry needs, and are supported by government.

An example of a typical project would be where student teams work on solving water management systems in a household by monitoring the water usage and identifying the 'hotspots of where water can be better conserved or re-used. Another project looked at best practice guidelines for the management of wastes in a meat processing company, to maximise resource and energy recovery. Such projects are industry-initiated, worked on by senior students who are supervised by University staff, and government sponsored. These are win-win-win partnerships, where industry gains fresh ideas, students gain real-life experience and the university's courses are relevant to society's needs. These projects are not only technical, but include financial feasibility, impact of sustainability, ethics and also consider society's long-term needs.

Recommendations: Some good practices in making these partnerships work is to communicate clearly the expectations at the start. The students' skills and capabilities should be made clear, industry and academic timelines need to be matched, and agreements must be signed at the start on who owns intellectual property (IP) that may be generated. At undergraduate level it is okay for the sponsoring company to own IP, as they have the infrastructure to commercialise the new product or service solution, while staff and students are more interested in publications. It is important for all parties to engage in this project and communicate throughout the duration of the project for mutual advantages.

5 CONCLUSION

This paper examines how the triple helix model has been integrated in tri-lateral networks (engineering, product design and business entrepreneurship) and focuses on developing an education system that cuts across both organisational and disciplinary boundaries. Industry needs more tech and business savvy individuals to solve complex problems that are trans-disciplinary. From a literature review and a study of current activities in engineering schools, clearly a new paradigm for engineering education is needed that can broaden students experiences and engagement. There are some initiatives taken but most of them are sitting outside the engineering space and their priorities and key objectives differ. Engineers need to accommodate a far more holistic approach to addressing social needs and priorities, linking cultural, economic, environment, legal and political considerations with changes in technology. Education needs to prepare students for the diversity and complexity of issues they may face in the future. Complex global issues are better solved with a network of key partners involving representatives from industry, community and government bodies.

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