Connecting Engineering Education in Universities to the Real World

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Abstract

Under the umbrella of the Imagination Research Projects Program, a three-year integrated project conducted by the College of Engineering and the Institute of Education, aiming to immerse creativity and innovation into engineering education has already come to an end in November 2017. During the past three years, it was observed that project achievement and performance was greatly restricted because of unclear cognition and understanding of creativity and innovation for participating teachers. Therefore, teachers did not act the most important role to enhance today's engineering education by inspiring creativity and imagination of students. In other words, not only students, teachers also need to be persistently educated ian many aspects in order to possess sufficient knowledge and capability to guide students for future engineering education. Another three-year project on cultivation of interdisciplinary professionals launched in December 2016 continues previous trend by embedding imagination and innovative thinking into current engineering education. In addition, this project has an additional objective of connecting engineering education in universities to the real world. A lot of efforts have been made to shorten the gap between theoretical engineering courses in classrooms and practical engineering problems in industrial environment. Those attempts include hands-on experiences in fundamental laboratory courses, calculation-based home works for fictitiously realistic engineering questions, and project-based capstone curriculum. However, most engineering teachers were well educated with engineering theories and concepts in mathematical and physical presentations. The disparity between contents in classrooms and practices in industry still exists. Limited knowledge and experience about actual industry business outside the campus happens to most engineering teachers in universities. For the purpose of elevating engineering teachers to a practical level close to the real world, this project focuses on assisting engineering teachers to absorb practical knowledge from four non-engineering aspects such as innovative thinking, entrepreneurial knowledge, industrial environment, and intellectual property and patent. This paper summarizes the background and contents of the project.

Keywords: *Creativity, innovation, engineering education, interdisciplinary learning;*

1. Background

Imagination has been a unique mind capability for human beings. It appears to be freely formed in a picture style without any visible or virtual restrictions. Furthermore, imagination comes with a powerful function of repetitive examination and modification. As a result, with stimulation and operation of the imagination, creativity is born to become the driving force for technology development and human civilization. Although the initial state of imagination is always untouchable, it is possible to turn the fictitious to applicable creativity with the help of expertise knowledge, practical skills, and experiences. It has been identified that three stages are engaged in scientific imagination processes: the initial stage, the dynamic adjustment stage, and the virtual implementation stage [1].

The 21th century has been declared as an era of creativity, which almost determines competitiveness. Ministry of Education of Taiwan recognized that the creativity played a crucial role to strengthen dominance of national since the year of 2000. A series of comprehensive creativity promotion projects were revealed. A typical one is the medium-range development plan for creative education, which includes multiple dimensions such as creative teachers, creative students, creative campus, creative think tank, creative academic training, international exchange, regional creativity, creative high schools, intelligent ironman creativity contest, creative development and practice, and creativity evaluation. In the White Paper on Creative Education by Ministry of Education of Taiwan released in 2002, the ultimate goal for creative education is to build a Republic of Creativity (ROC), which has the same abbreviation with the Republic of China, in 21th century. Nevertheless, it can be found that most emphasis of the creative education plans was on education in elementary and high schools. Although students in colleges absorb sufficient professional knowledge and practical skills for the need in real

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world, they still require ability of creativity and innovative thinking to overcome various challenges in the future.
Engineering education in colleges always focuses on expertise knowledge and skills to prepare for future needs in professional domain. Therefore, deeper and broader coverage in engineering education to strengthen students' engineering capabilities becomes the goal to be pursued by almost all universities. But insufficient connection with practical real world is always found, such as innovation, creativity, risk assessment, communication and presentation, conflict coordination, project management and team work. As a result, project-oriented education has been a popular solution to link engineering education in universities with industrial demands [2]. The project-based learning is a student-driven and teacher-facilitated learning approach [3]. This approach is able to clarify the purpose of learning and study to practise for students. Learning motivation can therefore be elevated and retraining after graduation in industry will be shortened.
In January 2009, the Assessment and Teaching of Twenty-First Century Skills Project (ATC21S) was launched at the Learning and Technology World Forum held in London. Six founder countries including Australia, Finland, Portugal, Singapore, England, and USA were involved. This project, originating from the paper 'A Call to Action', was designed by a taskforce from three major technology companies in the world, Cisco, Intel, and Microsoft. Two areas were targeted for assessment and teaching purposes: learning through digital networks and collaborative problem solving. This project has major implications for teaching and education policies in the future. Ten skills classified into four groups: ways of thinking, ways of working, tools for working, and living in the world were raised in this project. The crucial 21st century skills listed in the group of ways of thinking consist of creativity, innovation, critical thinking, problem solving, decision-making, and learning to learn [4].

2. The interdisciplinary talent development project

Based on the same idea and motivation, under the umbrella of the Imagination Research Projects Program introduced by the MOST (Ministry of Science and Technology), the College of Engineering of National Sun Yat-Sen University cooperating with the Institute of Education conducted a three-year integrated project entitled "Research on Innovations in Engineering Curriculum and Modularized Technology Special Topics" since December 2014. The objective of this integrated project is to examine the growth of creativity in selected courses of all the departments and institutes in the College of Engineering [5]. While conducting this project for the past three years, participating faculty members deeply recognized that limited understanding about creativity and innovative thinking existed for them. Therefore, teachers did not play a crucial role to lead students towards the goal of this project. According to this shortcoming, a subproject 3 in a new three-year interdisciplinary talent development project sponsored by MOST starting in December 2016 was initiated to aim at teaching innovation for teachers. This interdisciplinary talent development project consists of four subprojects. Subprojects 1 and 2 focus on curriculum development from industrial and fundamental engineering aspects, respectively. In order to directly connect with industry, subproject 2 is jointly sponsored by industrial companies. Selected courses related to interdisciplinary engineering education from four departments and two institutes in College of Engineering are associated with subproject 2. The subproject 4 handled by Institute of Education is in charge of assessment for learning performance of students. The subproject 3 is the only subproject on teachers' side with the objective of enhancement of teachers' growth and progress especially on creativity and innovation. It is believed that only teachers with innovative thinking can cultivate students with ability of creativity and innovation. Figure 1 illustrates the relationship among those four subprojects and groups of teachers and students.

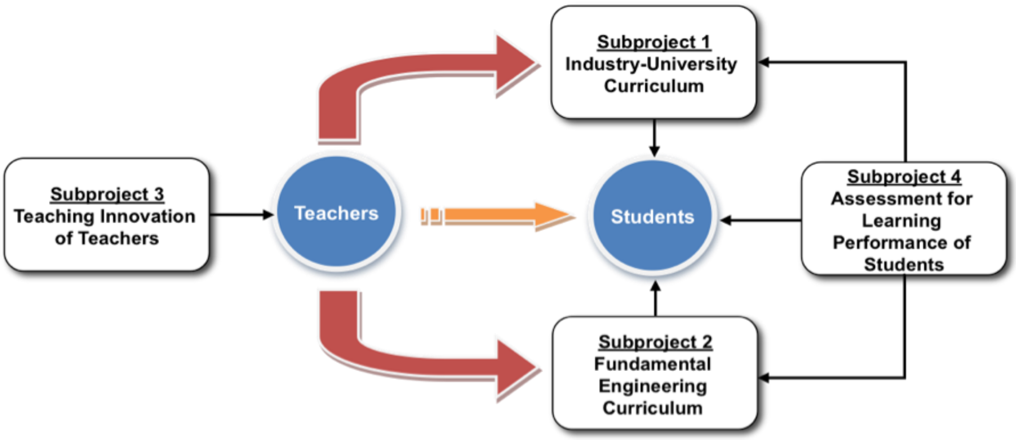

Figure 1: Framework of the on-going interdisciplinary talent development project

2. Strategies of other universities

Development of innovative thinking and creativity for faculty members in higher education was already implemented in some institutions and universities. Besides, in order to allow research accomplishment in engineering domains can respond to industrial needs, educational institutions also endeavour to fill the gap between academic theorems and practical engineering.

2.1 Massachusetts Institute of Technology

Massachusetts Institute of Technology (MIT) has been a distinguished engineering school for many years. The media laboratory in Department of Architecture and Urban Planning, established in 1985, aims to promote anti-disciplinary research culture by breaking boundary of existing academic fields [6]. They encourage unconventional approaches especially cooperation between media arts and technology so that unexpected research results and some foresight breakthrough can be generated. For the time being, more than 150 companies have been founded from the Media Laboratory.

In addition, under the College of Engineering of MIT, a Deshpande Center for Technology Innovation was founded in 2002. This center is market-oriented and provides a platform to commercialize innovations from all members in the school [7]. It offers two types of grants, the ignition grants and the innovation grants. The ignition grants allow applicants to work on a prototype by conducting preliminary exploration study including pilot experiments, literatures review, and assumptions verification. The innovation grants then move the innovative products forward to actual markets. The ultimate goal is to draw attentions and funding from industry companies for the innovation.

2.2 Princeton University

In 2005, Princeton University, a member of the Ivy League, formed the Keller Center, which has the similar functions and purposes with the Deshpande Center for Technology Innovation at MIT, in the School of Engineering and Applied Science. It emphasizes interdisciplinary integration of engineering, humanities, arts, social sciences, and natural sciences by providing training courses for the purposes of application of learned knowledge and technologies [8]. All the curriculums are constructed from four key dimensions including create, learn, explore, and engage, to strengthen students' creativity and connection between classrooms and industry.

2.3 Stanford University

On the west coast of the United States, Stanford University established the Epicenter sponsored by National Science Foundation in 2012. The objective of the Epicenter is to let engineering students be capable of understanding entrepreneur and innovation, which will produce significant effect in their future, in their college life [9]. The central goal is identified as enhancement of the tie between technology-based innovation and the industry. Since the Epicenter is financial supported by the government, it serves all universities, institutions, and research organizations in US.

3. Teaching innovation of teachers

According to strategies from those three renowned universities in US described in last section, some common grounds can be summarized as follows:

- Interdisciplinary integration and innovation can benefit from breaking wall between existing academic areas.
- Engineering researches should not be away from practical world and need to be always linked with society around us.
- Training in departments of science and engineering emphasizes on fundamental academic knowledge. Although experiment courses are provided to instruct practical skills, assistance from four dimensions to transform research results to commercial products is still strongly demanded.
- Dimension 1: Innovative thinking – Only products with innovation ideas own market values.
- Dimension 2: Entrepreneurial knowledge – Most engineering faculty members were not educated with sufficient entrepreneurial knowledge. In order to bridge industry and academic researches, engineering teachers need to have necessary background about how to start a business.
- Dimension 3: Industrial environment – For the purpose of making correct decisions, engineering teachers have to be familiar with industrial environment such as market trend and industrial movement.
- Dimension 4: Intellectual property and patents – In order to protect originality and collateral benefits of the innovation, intellectual property and patents become inevitable issues in entrepreneurial process.

Based on the analysis results listed above, traditional engineering education may not be enough for engineers in 21^{st} century. In other words, engineering students have to be involved with other knowledge including innovative thinking, entrepreneurial knowledge, industrial environment, and intellectual property and patents, in addition to professional expertise, as depicted in Figure 2. Therefore, the subproject 2 entitled "Teaching innovation of teachers" is planning to help engineering teachers developing their knowledge enlargement along those four dimensions outside engineering domains by the approaches of seminars and workshops. At the same time, their capabilities of innovative thinking and creativity will be intangibly consolidated. Therefore, engineering students can accumulate more and broader practical knowledge and skills regarding the world beyond the campus through their teachers. The responsibility of engineering teachers in 21^{st} century is not only to instruct engineering knowledge, but to guide and connect the students to the industry in the real world.

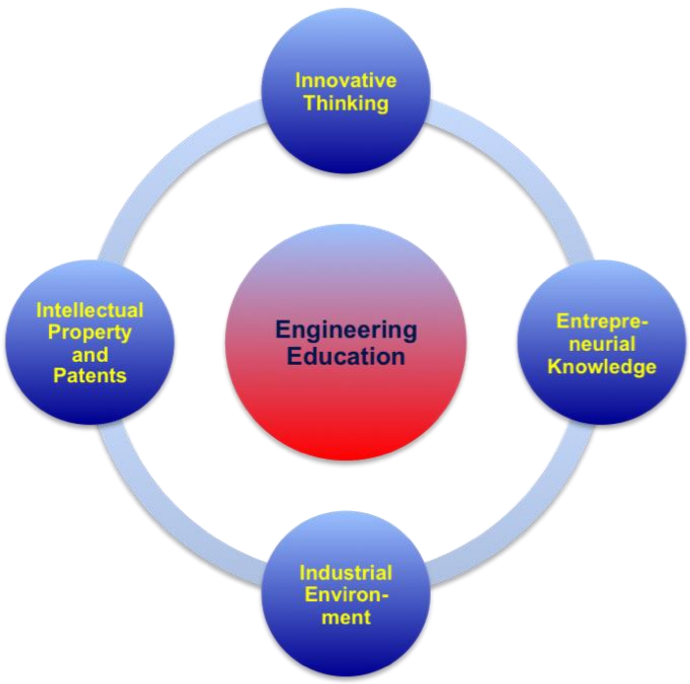

Figure 2: Essential non-engineering skills classified in four dimensions for engineering education in 21th century

4. Summary

Engineering knowledge and skills are not enough for college students in 21^{st} century to closely link with industry. What they require appears not to be in conventional engineering textbooks. The on-going three-year interdisciplinary talent development project tends to bridge the engineering education in universities and industry by incorporating innovation, imagination, and problem-solving capability into interdisciplinary curriculum. Specific goals of each subproject are:

1. Development of interdisciplinary basic engineering courses to cultivate students' fundamental engineering skills,
2. Development of interdisciplinary applied industry-engineering courses to enrich students' application skills,
3. Establishment of a teaching innovation platform to support teachers' teaching reform and improvement, and
4. Assessment for learning performance of students to justify effectiveness of teaching innovation.

Based on approaches presented by other universities, essential non-engineering skills for engineering education in 21st century can be classified into four dimensions: innovative thinking, entrepreneurial knowledge, industrial environment, and intellectual property and patents. The subproject 2, "Teaching Innovation of Teachers", is proposed to expand teachers' horizon and vision along those four aspects. It is highly expected that the gap between academic engineering and industrial practice can be reduced so that engineering education in universities powered by innovation thinking will connect to industry in the real world.

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