THE DEVELOPMENT OF MAKER-DRIVEN ENGINEERING TRAINING CENTER

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ABSTRACT -The ever-growing maker movement around the globe has achieved a new level. Education through maker in universities has unique characteristics, especially when it affects the development of engineering training centers in Chinese universities and colleges. Tsinghua i.Center has a long history of engineering education, general education, and entrepreneurship education. Based on the practical experience of integrating engineering training into various programs, i.Center has built a series of platforms for engineering competence training, engineering quality education, and innovative capability training. Furthermore, through integration of maker culture, maker spirit, and maker generated content, i.Center keeps improving the quality of hands-on education programs as well as the level of the entire organization.

KEYWORDS - innovation and entrepreneurship, open innovation space, Tsinghua i.Center, trans-discipline, maker movement

Modern engineering training is an important part of hands-on engineering education. It is irreplaceable in enhancing student’s practical engineering capability, in improving comprehensive quality, in nurturing innovation competence, etc. In recent years, as engineering training centers in China have been upgrading equipment, facilities, and other infrastructures, the need to update the direction for development, the functional positioning strategy, and the system and methodologies for education, has become more urgent than ever. The maker movement is becoming a global trend, and its essence is the process of realizing the ideas. Tsinghua i.Center pioneers in introducing maker education into university, and has made efforts in building an open environment for interconnecting makers to academic disciplines. With its strength in industry-level, inter-disciplinary, innovative, international contents, i.Center provide the students with intra- and extra-curriculum learning activities, making significant achievement.

1.1 EDUCATIONAL PURPOSE OF ENGINEERING TRAINING

Engineering training programs in Chinese universities and colleges are originated from metal machining practices for students in engineering or mechanics majors. Although the two genre of training program shares some key elements, yet there are some fundamental differences in between. Engineering training programs are more advanced than metal machining practices in their stronger educational purposes, more adaptive contents, wider coverage over various majors, as well as more comprehensive curriculum. Tsinghua i.Center has been working on integrating engineering education, general education and entrepreneurship education to deliver advanced training programs with an emphasis on educational purposes. i.Center devoted to deepening the core contents and widening the boundaries of knowledge involved in comprehensive training programs. In short, the objectives for i.Center could be described as to build an engineering competence training center facilitating the incubation of distinguished engineering talents, to establish a educational platform for innovation and entrepreneurship nurturing elite inventors and entrepreneurs, and to construct a hub for inter-disciplinary engineering culture education.

1.1.1 The engineering educational purpose

Engineering training is an important part of higher education for practical engineering competence. The fundamental characteristic of engineering education is how it is carried out with practices and hands-on activities. Since engineering is more about application, comprehension, and practical implementation, engineering practices is irreplaceable in engineering education and is a distinguishable part among other types of higher education. In recent years, many countries in the world has begun to adapt and strengthen practical engineering education according to the need of domestic development. In many higher engineering education plans and curriculum, on-campus practical engineering practices has been integrated with out-of-campus engineering practices and trainings. In 2013, China has become the 21st signatory for Washington Accord, with wide acceptance among existing members. The acknowledgement of engineering degrees is realized through sharing and acknowledging the standards and certification criteria of engineering education. In China, many universities has made applications for ABET certification, which will promote the establishment of professional quality control system for education and the creation of a formalized, well-grounded, internationalized system for undergraduate education.

Engineering training is a major way to carry out modern practical engineering education. Faculties, infrastructures, curriculum are the three pillars for engineering practices. Properly distributed resources will promote students to comprehend theoretical and practical knowledge and to implement both. Tsinghua i.Center introduced the CDIO methodologies into engineering training courses. The students are engaged with problem-, project-, and case-based challenges. The objectives can be generalized as to pass on engineering knowledge, to form engineering practical abilities, and to enhance comprehensive qualities. The idea is to cultivate the spirit and the capability of innovation, to shift the focus from the process of teaching to the process and outcomes of students’ learning, and to apply continuous improvement to the process of learning.

Tsinghua i.Center has systematically updated the engineering training curriculum as well as its supporting material according to the 11 skill dimensions in ABET student learning outcome assessment. This has not only brought about the application of renovated learning models, but also provided guidance for education reforms. By streamlining and optimizing the sections of engineering training, i.Center made its efforts in developing the contents that has direct connection to students achievements. Furthermore, i.Center also collaborates with other departments that applied for ABET certification, and customizes the modularized sections according to the curriculum of each department.

1.1.2 The innovation and entrepreneurship educational purpose

In Tokyo 1991, Conference of UNESCO defined entrepreneurship education on a broad scale as to train individuals with entrepreneurship, which is also important for the salaried people. The process involves nurturing creative pioneers who knows how to be original, to take risks, to start up a company, to work in group, to deal with technical and social problems, to do effective management, and to make social connections. In many countries, entrepreneurship education is among the top priorities of higher education. The United States has been leading the education for innovative and entrepreneurial talents. The U.K., Germany, and Japan have also formed strategies of their kinds. In China, pushing entrepreneurship education to a larger scale is urgently needed as the society is within a process of innovation-driven development strategy and the economy is upgrading to a more state. It is also the foundation for the national strategy of ‘popularized entrepreneurship and mass innovation. Promoting entrepreneurship education is also the pivot for the transformation of higher education in general.

Based on its original function as an educational institute, Tsinghua i.Center has established a service platform for 3Is, namely ideas, innovation, implementation (aka entrepreneurship). In 2014, i.Center is granted Exemplary On-campus Innovation Practice Base for Higher Education in Beijing. Through integrating internal and external resources, i.Center renovated the system for innovation practices and education. The programs are led by interests and aspiration, and are carried out with hands-on activities. The ultimate goal is to interconnect students and faculties from various majors of engineering, literature, social sciences, etc. together, and to coordinate the three aspects of education, shaping values, practicing skills, and passing on knowledge.

The educational system in i.Center has multiple sections of various levels, including general education for wide coverage, vital characters improvement, and comprehensive innovation projects. The programs cover intra- and extra-curriculum activities, combining theoretical and practical training.

1) *General innovation education for wide coverage*. The engineering training courses cover hundreds of students in each semester. i.Center transforms the courses through implementing problems-, project-, case-based teaching and learning methodologies within major sections, merging cross-disciplinary students together, while making adaptation according to each students. The learning activities are designed to connect two parallel lines of means and goals. The means of learning include acquisition, implementation, and comprehension, while the goals include knowledge, skill, and quality.

2) *Hands-on activities and contests for innovation*. i.Center provide supportive platform for on-campus hands-on activities and contests covering most of majors and disciplines. The students utilize the platform to design, manufacture, assembly, test, and tune whatever they need for the activities. With multi-purpose data collection and analysis infrastructure, participants are also enabled with performance tracking throughout the process. Each year, i.Center serves more than 8000 visitors and participated in more than 10 student projects.

3) *Courses and projects for innovation and entrepreneurship*. Over the year, i.Center has hosted several student research teams and start-ups, including Association of Innovation Student Club, Student Research Club, Entrepreneurship Trainees, etc. Faculties of i.Center are always popular tutors for Student Research Training programs in the university. With the rising demand from the students, i.Center began to offer more than 10 courses related to innovation and entrepreneurship, including ‘*Advanced Manufacturing and Innovative Making*’, ‘*Creative designing and manufacturing*’, ‘*Entrepreneurship knowledge and practice*’, ‘*Introduction to start up a company, with 16 top entrepreneurs*’, etc. Faculties of i.Center keeps working together with experts from other departments and outside of the universities to improve and update these courses, so as to provide stronger innovation education and more professional support for research projects and entrepreneurial projects.

1.1.3 The general and liberal educational purpose

Significant contemporary challenges and problems of economy, society, technology, environment, etc., are usually of great complexity. People always deal with them with multiple disciplinary efforts. General education and liberal education has come back in mainstream in many countries as an important section of higher education. Engineering education for students in literature, art, or science departments are not simply about introducing technologies, or knowledge. It is about how to equip them with engineering literacy, to get them familiar with engineers’ way to solve problems, and convey the engineers’ way of thinking.

In recent year’s of practice, i.Center has devoted to develop engineering culture proficiency courses, becoming the hub for inter-disciplinary communication and combination among majors of science, engineering, social science, humanities, arts, etc. For example, ‘Experiencing manufacture engineering’ adopts project-based learning model, ‘Entrepreneurship knowledge and practice’ provides the students with the opportunities to make creative designs and realize them, while 16 topics in ‘Laboratory research exploration’ course pack provide the students with on-site industry-level equipment and facilities to work with. These courses constitute a framework for inter-disciplinary learning. The course modules are customized and adapted based on the distinguished needs and preferences of students from different background, while the students are also grouped to maximize major and background diversity. Tutors guide the student teams to explore, implement, and iterate the solutions until satisfaction. As students from majors of literature, arts, social sciences, etc. are enrolled in class, teamwork becomes even easier and more effective. Every student become more involved since they are motivated through their own interest. These hand-on projects act as catalysts for students from non-engineering backgrounds to get engaged with engineering proficiency education and get inspired to create and make.

In December 2012, in a seminar on engineering proficiency education and course design and development, delegates from more than 10 universities around the nation discussed about how to promote general engineering proficiency education. The seminar proposed that it is of great significance and value to begin theoretical studies and practical pilot programs based on the concept of engineering cultural proficiency. Tsinghua has long been strong in engineering disciplines. This advantage may play a different role in converting from traditional engineering education to engineering empowered culture studies. The goal is to promote the proficiency of both university students as well as faculties.

1.2 MAKER-DRIVEN DEVELOPMENT OF ENGINEERING TRAINING CENTERS

1.2.1 Makers and maker education

What today’s makers do can be traced back to days when people started to love DIY (do it yourself). However modern makers can utilize global resources by sharing contents via the Internet. They learn from each other and form maker communities globally and locally. As these communities can quickly learn and utilize open-source hardware/software, they gain advantages in leading the development of new technologies as well as in their scale. Consequently, makerspaces in many places in the world emerge and become the gathering locations for maker communities to share, to produce, and to demonstrate their ideas. These makerspaces have varying functions and run in different ways, according to their local cultures, surrounding industry resources. Yet makerspaces are usually equipped with manufacturing facilities ranging from handicraft devices to machining tools. Meanwhile, as these spaces are supported by communities, there are usually places for sharing ideas and having discussions. The size of the space is not always vital important for makerspaces, but the core idea is to have a place for people sharing similar interests to be together. Through sharing and peer-learning, people are motivated to keep making things happen.

The Hackerspace Movement is a leading trend in technology. The concept of makers and makerspaces are becoming more popular among peoples. The spirit of makers can be generalized as being pioneering, open, collaborative, willing to share, entrepreneurial, and practical. Makers are never makers if they did not realize what they have in mind. These communities are becoming the driving force for a new round of Industrial Revolution worldwide.

After years of development, Tsinghua University has formed an advanced innovation education package, with its unique features. Furthermore, introducing maker elements enhances the objectives and the effectiveness of education for entrepreneurs and innovative talents. In Tsinghua, maker has a broader definition including those who practice in innovation and entrepreneurship projects. It is an expansion to the essence of maker that emphasizes the process of realization of ideas. The value lies in the choice a maker makes at the beginning of an idea. Since they make their own decisions, they need to take the responsibility to complete their mission, which is an important part of on-campus maker activities. When they have the awareness of independent responsibility, they are gradually gaining the spirit of contract, of entrepreneurs, and of inventors. Besides, when the students are fully engaged in the learning activities and the practice for starting up a project, they can gain more experience and achieve a higher level.

1.2.2 Maker-driven development of an engineering training center

In recent years, Tsinghua i.Center led several joint projects with Academy of Arts and Design, Department of Industrial Engineering, Department of Automation, etc. Based on these experience, various kinds of resources are joined together to develop the inter-disciplinary maker workshop in i.Center. Meanwhile, i.Center also brings in social resources outside of the campus, including maker communities and engineers. Students works with these people together, utilizing hundreds of industry-level machining tools within 16,500 square meters of space, including machining tools, CNC machining centers, laser cutting machines, 3D printers, etc. In the near future, Tsinghua i.Center makerspace will be open to not only students, but makers outside of the campus.

Tsinghua i.Center provides the students with high level manufacturing and idea realization facilities that a common makerspaces usually cannot offer. These facilities will give student makers the opportunity to operate tools used in real factories for mass production. This will help shorten the path between an immature idea and a ready-to-produce design. The innovation practice supporting platform as well as the online community are still involving, yet already have several achievement in team building, design thinking, prototyping, manufacturing consultancy, etc. This platform has become the cornerstone for on-campus innovation projects.

Based on these advantages in resources, i.Center organized a series of learning activities with maker culture and project-based innovation methodologies. Hands-on practices have larger proportions in course designs than ever, so as to enhance the learning performance. Maker-based courses usually have such features as short in course length, rich in disciplinary composition, and focus on outcomes. The themes are usually about electronics products or mechanisms, such as automatic material transportation system, low-cost nano-level atomic force microscope, IOT products, etc. Students propose solutions according to the requirement of the theme and realize the concept for demonstration. Maker activities are usually complementary for existing innovation or entrepreneurship courses. The format of makerspaces and maker-style hackathons are usually effective for inspiring students to be creative and original.

Building a makerspace is a booster for the development of i.Center. The idea of making i.Center a place for transforming students into realist of dreams drives us to keep inspire the students to let out their interests and aspiration. Practical innovation activities will help release the potentials of students. In terms of system building, i.Center create an open platform for maker activities and an open curriculum for innovation and entrepreneurship, with incubation service, technology tutorials, product development, customized manufacturing, consultancy, etc.; in terms of running model, the courses and activities are oriented by students, which creates the motivation for larger groups of students to get involved and brings in the atmosphere of creation, innovation, and entrepreneurship to campus; in terms of scale, one out of three students have directly participated in maker-based learning activities; in terms of system, an open structure for people to get involved is under development for students, faculties from various backgrounds, as well as experts, makers from various companies and communities to become part of Tsinghua maker community, which will become a massive place for creative learning.

1.3 CONCLUSION

1) Engineering training centers should target at deepening the content while expanding the boundaries, while exploring and implementing the ways to converging engineering education, general education and innovation/entrepreneurship education together.

2) Makerspaces on campus is a booster for innovation and entrepreneurship education. It will help create the atmosphere, bring about topics for research, lead the direction of education, spread the spirit, and enhance the positive influence of maker culture to a larger scale and to a more fundamental extent.

3) Maker education provide the students with a platform to try, to make error, and to amend. Through teaching methodologies, informing cutting-edge technologies, making strategic plans, and integrating systems, students are under constant guidance and cultivation. The goal is to help students gain insights of real industry development.

4) Engineering training center can benefit from introducing maker education through creating a workflow to bringing inter-disciplinary contents together. This will generally raise the level of training centers.

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