Improving the Professional Competences of Engineers to Achieve the Sustainable Development Goals

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Abstract. The Sustainable Development Goals (SDGs) proposed by UNESCO draw the global map of sustainable development including engineering education. In China, ‘Strategy of Innovation-driven Development’ & ‘One Belt One Road’ not only brought new opportunities and challenges to the engineering education, but also had great influence on the trend of continuing engineering education in the future. To investigate the current situation of the graduates’ professional competences of continuing engineering education, and promote the sustainable development of the professional competences of engineers, the research group did the survey in Tongji University in November 2015. The survey used the random sample of engineering graduates among four engineering majors including Architecture, Civil Engineering, Mechanical Engineering, and Traffic Engineering. Data descriptive statistics and correlation analysis were processed by SPSS software. This paper has concluded that the continuing engineering education should be connected with formal engineering education effectively, improve the professional competence of the students’ solving the real problems and teamwork, and reinforce the engineering ethics. On the other hand, the continuing engineering education should be integrated into the global environment, broaden the global perspective of teachers and students, cultivate student’s ability of cooperation and adaptation to cross-cultural environment. Thus it can improve the quality of continuing engineering education and push the engineering education toward sustainable development goals.

Introduction

With the development of engineering technology and the global changing environment, more and more engineers had to be faced to the sustainable development of their career, and continuing engineering education (CEE) has more opportunities and challenges. The Sustainable Development Goals (SDGs) proposed by UNESCO in August 2015 had integrated and balanced sustainable development in three dimensions - economic, social and environmental. Goal 4 - Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all, and Goal 9 - Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation, are relevant to engineering education [1]. In China, ‘Strategy of Innovation-driven Development’ & ‘One Belt One Road’ will have great influence on the trend of CEE in the future. Scientific and technological innovation provides strategic support for raising the productive forces and boosting the overall national strength, and we must give it top priority in overall national development [2]. To implement the strategy of innovation-driven development, it must be in core position overall the country’s development. In March 2015, Chinese government issued ‘Vision and Actions on Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road’, pointed out to improve the region's infrastructure [3]. It not only extends the regional cooperation, but also gives more opportunities to the engineers to participate in the international projects. CEE will be more and more important to both engineers and engineering in the sustainable development in the future.

CEE, also known as ‘the engineer’s education’, means professional education to the on-the-job engineering technical personnel graduated from the colleges and universities, in order to maintain their advanced knowledge, skills and competences, and to keep innovation in the work [4]. The
objectives of CEE focus on updating the engineer's knowledge, skills and competences. The UK Standard for Professional Engineering Competence (Engineering Technician, Incorporated Engineer and Chartered Engineer Standard), says that ‘Competence is the ability to carry out a task to an effective standard’ [3]. In November 2013, the Ministry of Education and the Chinese Academy of Engineering issued The General Standards of Excellent Engineers’ Education and Training Programs which put forward to the basic requirements for all kinds of engineering personnel [6]. And it is the basic document of guiding the excellent engineers’ education in China.

China is the biggest country in engineers’ educating and training all over the world. The amount of engineering graduates for bachelor’s degree in general education was 1,132,226 in 2014, about 33.17% of the total. The amount of engineering graduates for master’s degree and doctor’s degree was 184,647, which was 34.46%. And the amount of engineering graduates for bachelor’s degree in adult education was 216,776, which account for 24.11% of the total [7]. It needs several years for an engineering graduate becoming an excellent engineer. How can an engineer adapt to the rapidly changing global environment? How can CEE deal with the opportunities and challenges? This paper has some conclusions based on the survey of the graduates of CEE. It is helpful to improve the quality of CEE and to push the engineering education toward sustainable development goals.

Research Design

To investigate the graduates' professional competences of CEE in the current situation, and promote the sustainable development of the professional competences of engineers, the research group took the survey in Tongji University in November 2015. The survey used the random sample among four engineering majors included Architecture, Civil Engineering, Mechanical Engineering, and Traffic Engineering. The questionnaire was issued for 250 graduates, 219 were returned, and 201 were valid. The questionnaire included four parts: (1) the basic situation of graduates; (2) the current professional competences of graduates; (3) the professional competences of an excellent engineer; and (4) suggestions to the CEE of educational institutions. The first three parts were multiple-choice questions. The last part was a short-answer question.

The first three parts used quantitative analysis, while the last part used qualitative study. Descriptive statistics and correlation analysis were processed by SPSS software. This paper analyzed the relationship between the variable of ‘working unit/working position’ and the variable of ‘the professional competences of an excellent engineer’. Then it took qualitative study for the last shot-answer question.

Statistical Results Analysis

Reliability and Validity Analysis on Questionnaire

The questionnaire had higher reliability and validity. Reliability refers to the credibility of the questionnaire, the main performance of the credibility and stability of the statistical results. The Cronbach’s Alpha coefficient was used to test the internal reliability of the questionnaire scale. The value of Cronbach's Alpha was 0.784 (>0.7), meant the questionnaire had a good structure and a higher data reliability. The design of the questionnaire was based on the reference of domestic and foreign research and experts’ consultation, so it had good contents validity.

Descriptive Statistics

The Basic Situation of Graduates. In the first part of questionnaire, the basic situation of graduates had been investigated including age, gender, title, working unit and working position. The data in the survey showed that: (1) most of the graduates from CEE were young and male; (2) more than half of them had intermediate and junior titles; and (3) most of them worked in design and construction units, and were in the technical and managerial positions. In details, 24.4% of the graduates were under 25 years old, the ages from 26 to 35 was 72.1%; 63.2% of them were male, and 36.8% of them were female; 5% of the graduates had advanced titles, 26.4% of them had
intermediate titles, and 31.8% had junior titles; The graduates who worked in design units were 49.3%, and who worked in construction units were 23.9%; 68.2% of them were in technical positions, and 19.9% were in managerial positions.

**The Current Professional Competences of Graduates.** There are two dimensions of professional competences included knowledge, abilities. The survey found that the professional knowledge and skills were the most important parts in the knowledge structures. And the graduates’ abilities showed three results: (1) international communication and innovation were weaker; (2) lifelong learning, engineering ethics and attitude were in the middle level; and (3) problem-solving abilities, information retrieval ability and team cooperation were stronger.

Analyzed from the knowledge dimension, 51.5% of the graduates thought that their theoretical knowledge were stronger, 17.5% and 16.5% considered that their relevant professional knowledge and knowledge of humanities & social sciences were stronger. Only 10.7% and 3.9% of the graduates admitted that their mathematics & nature science or knowledge in other subject areas were stronger.

Analyzed from the abilities dimension, 67.2% and 59.7% of the graduates felt that their international communication and innovation were weaker; 21.9% 20.4% and 19.4% of the graduates felt that the abilities of lifelong learning, engineering ethics and attitude were weaker; and less than 16% of the graduates felt that their abilities of solving problems, cooperation and information retrieval were weaker.

**The Professional Competences of an Excellent Engineer.** The professional competences of an excellent engineer should contain both knowledge and abilities. The data in the survey showed that an excellent engineer should have three kinds of knowledge: (1) the theoretical knowledge of the subject area and the professional knowledge of relative disciplines; (2) the mathematics & nature science or knowledge in other subject areas; and (3) knowledge of humanities & social sciences. At the same time, an excellent engineer should also have three kinds of abilities as follows based on the survey data: (1) abilities in design and development, engineering practice, communication, problem-solving ability, safety and risk management; (2) leadership and management skills, innovation, lifelong learning ability, mental capacity, teamwork, engineering ethics and attitude; and (3) global communication, information retrieval ability and others.

From the survey, in the aspect of the knowledge which an excellent engineer should have were as follows: 82.6% and 85.1% graduates believed that the theoretical knowledge of the subject area and the professional knowledge of relative disciplines were the most important knowledge; 28.4% believed humanities & social sciences were the most important knowledge; and only 12.4% believed that knowledge in other subject areas were the most important.

![Figure 1. The professional competences of an excellent engineer.](image_url)
A total of 14 options were listed in terms of the ability structure of an excellent engineer. More than half of the graduates believed that good abilities in design and development, engineering practice, communication, problem-solving ability, safety and risk management were the most important to an excellent engineer. The percentages were 69.2%, 64.7%, 59.2%, 54.2% and 50.7%. Nearly 40% of the graduates believed that teamwork cooperation, innovation, mental capacity, leadership and management skills, lifelong learning ability, engineering ethics and attitude were more important. And only 20.9% and 24.9% of the graduates believed that global communication and information retrieval ability were important, as indicated in Figure 1.

Correlation Analysis

Research Hypothesis. This paper adopted hypothesis testing method analyzed the correlation between the variables of ‘working unit/working position’ and ‘the competence of an excellent engineer’, in order to analyze the relationship among variables. First, null hypothesis was proposed for the relationship between variables. The null hypothesis means that there is no difference between the general sample and the current sample, that is, there is no difference between the variables studied or correlation [8]. Then it uses reduction to absurdity, and hopes sample information to reject the null hypothesis, namely ‘small probability event actually would be impossible’. It was assumed that there was no positive correlation between variable A and variable B, and the research hypothesis was coded.

Hypothesis Testing and Correlation Analysis. Pearson correlation coefficient and significant P value were calculated by SPSS statistical software. Pearson correlation coefficient is divided into positive correlation, negative correlation and independence. If the P value is less than the critical value, then the null hypothesis would be rejected. If P≤0.05, indicates significant difference; If P≤0.01, indicates extremely significant difference. The research hypothesis codes and the results of hypothesis testing were described. According to the hypothesis testing results, there is correlation between ‘working unit/working position’ and ‘the competence of an excellent engineer’, which could be observed as follows:

There were correlations between ‘working unit’ and ‘the competence of an excellent engineer’: Concerned with the variable of ‘design unit’, it was extremely significant correlation to ‘knowledge of humanities & social sciences’ and ‘abilities in design and development’, and it was significant correlation to ‘knowledge of mathematics & nature science’ and ‘teamwork cooperation’; Concerned with ‘construction unit’, it was extremely significant correlation to ‘leadership and management skills’, and it was significant correlation to ‘safety and risk management’ and ‘engineering practice’; Concerned with ‘advisory unit’, it was significant correlation to ‘leadership and management skills’, ‘innovation’ and ‘other abilities’; Concerned with ‘supervision unit’, it was extremely significant correlation to ‘lifelong learning’.

There were correlations between ‘working position’ and ‘the competence of an excellent engineer’: Concerned with ‘management position’ of graduates, it was extremely significant correlation to ‘safety and risk management’, and it was significant correlation to ‘mathematics & nature science’, ‘communication’, ‘engineering practice’ and ‘engineering ethics and professional attitude’; Concerned with ‘technical position’, it was significant correlation to ‘abilities in design and development’, and it was significant correlation to ‘mental capacity’.

Thus, it can be seen that followed that for most of the graduates who worked in the design and construction units, and mainly engaged in technical and managerial positions, needed to update their knowledge and improve their professional competence. They should establish the concept of lifelong learning, and maintain the sustainable development of their own career.

Qualitative Analysis

Through the qualitative analysis to the last shot-answer question of the questionnaire, the graduates hoped educational institutions to reform in vision and ideas, academic programs and teaching design, and to help them improve their professional competences.

Vision and Ideas. From the survey, the graduates wanted educational institutions to achieve in
four aspects. First, the institutions should have opened-mind, strengthen the cooperation between institutions and enterprises actively, and provide good opportunities for students to develop their ability to innovation. Second, the institutions should not only pay more attention to teaching theories, but also to engineering practice. Third, the institutions should arrange the teaching schedules by considering the students real difficulties. At last, the institutions should guide the students to receive higher level education.

**Academic Programs.** In the aspect of the academic programs, the graduates hoped the stakeholders such as enterprises could attend to the process of developing the academic programs. They advised to combine curriculums with practice, and the contents were updated and connected to the science and technology. In terms of the design of project and graduation thesis, more graduates believed that it was important to combine teaching with engineering practice in order to improve the working skills and professional competences. They also desired to have good chances to practice and communicate with other working units, and to have opportunities to take part in engineering research projects.

**Teaching Design.** In teaching design, the graduates thought that teachers should not only teach the theories but also share the engineering cases. Some practical software could be taught to the students such as CAD, PRO-E, PROJECT, etc. Field investigates and exercises could be taken within engineering teaching. Vocational training, knowledge competitions and relative activities should be taken by educational institutions.

**Discussion**

**CEE Connected with Formal Engineering Education Effectively**

CEE has internal connection to formal engineering education. Both of them are the parts of the lifelong education system to the engineers. Formal engineering education are faced to the full-time students of higher education, and the goal is to educate the engineering students in research-oriented. The colleges and universities need to develop students’ competences standards in accordance with the ‘Excellent engineer education and training program general standards’ published by the Ministry of Education. Besides the engineering theoretical knowledge of the subject areas and the professional knowledge of related disciplines, the students should grasp the mathematics & nature science or knowledge in other subject areas, knowledge of humanities & social sciences. And they should also have strong abilities in solving problem, innovation, global communication, especially in lifelong learning and sustainable development.

But CEE is mainly faced to the part-time students who are mainly engineers and technicians, and the goal is to update the knowledge and improve the professional competences. CEE is the extension of the formal engineering education, and it should be connected with formal engineering education effectively. Through CEE, the students can improve their engineering practice and teamwork and strengthen the engineering ethics and attitudes in order to improve their professional competences. Thus, CEE can not only meet the requirements of the engineer's own sustainable development, but also meets the demand of society, economy and environment. The educational institutions should insist on the core principle of updating the knowledge and improving the competences through the process of developing the academic programs, curriculums and teaching designs in order to achieve the goal of fostering CEE application-oriented talents. In the UNESCO’s 2010 report ‘Engineering: Issues, challenges and opportunities for development’, there was clear urgency and a call to transform engineering education, curricula and teaching methods to emphasize relevance and a problem-solving approach to engineering. The academic programs should be launched not only to expose to the various fields of knowledge, but also to reflect the development of engineering technology and practice. And programs should be relevant to the needs of the economy and society. Curriculum design and teaching design should be satisfied with the needs of engineering practice based on students-centered. The institutions should also have close relationship with the enterprises and cooperate with science research, teaching practice and graduation design. Double tutorial system can be used.
CEE Integrated into the Global Environment

CEE is connected with the global environment closely. With the sustainable development of economic, social and environmental areas, CEE should be integrated into the global environment in order to improve the knowledge and competences of the engineers to adapt to the ever-changing working environment. Through CEE, the engineers can access to the path of improving knowledge, skills and competences for their vocational careers. Also, CEE can also create conditions for engineers to adapt to the global environment. First of all, the vision of students should be expanded through CEE, especially the international perspective. The international cooperation and communication should be held frequently on the international platform relying on the advantage of disciplines of institutions. And it can help the students follow the frontier of engineering science and technology. In addition, the ability of cooperation and adaptation to the cross-cultural environment should be cultivated by CEE. With more and more engineers going abroad, they need to reduce the cultural differences and psychological distance, and adapted to the cross-cultural environment. As professional educators, we cannot continue to deliver quality products around the world without adapting our methods of teaching to meet the cultural expectations. Other training courses could be held for the engineering students, such as anthropology, psychology, linguistics, sociology and other disciplines. It can help engineering students understand and adapt to culture differences.

Summary

In conclusion, CEE needs to deal with many challenges from society, economic and environment actively to improve the knowledge and competence of engineers. On the one hand, CEE should be connected with formal engineering education effectively, improve the professional competence of the students’ solving the real problems, and reinforce the engineering ethics. On the other hand, CEE should be integrated into the global environment and broaden the global perspectives of teachers and students, cultivate student’s ability of cooperation and adaptation to cross-cultural environment. Thus it can improve the quality of CEE and push the engineering education toward sustainable development goals.

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