# Globalization: Comparing Chinese and US Electrical Engineering Undergraduate Program

**Dr. Hui Zhong, Shandong University/Gannon University**

Born in P.R.China on September,1974, obtained B.Eng. M. Eng and Ph D degree rom Shandong University in 1996,1999 and 2009 respectively. She is a a lecturer with the School of Electrical Engineering, Shandong University and now she is a visiting scholar with Engineering and Business College, Gannon University Her teaching courses include Circuits, Electromagnetic Field, Electrical Machine and Electric Drives. Her research interests include permanent magnet machines, special electrical machines, where she has published more than 20 papers.

**Dr. lin zhao, Gannon University**

Lin Zhao received the Ph.D. degree in electrical engineering from the University of Western Ontario, London, ON, Canada in 2006. She received the B.Sc. and M.Sc. degrees in electrical engineering from Shandong University, Jinan, China, in 1993 and 1996 respectively. From 1996 to 2002, she was a Faculty Member with the School of Control Science and Engineering and the School of Electrical Engineering, Shandong University. From 2002 to 2007, she was first a Research and Teaching Assistant and then a Postdoctoral Fellow with the Applied Electrostatic Research Center, the University of Western Ontario. Since 2007, she has been with the Department of Electrical and Computer Engineering, Gannon University, Erie, PA, where she is currently an Assistant Professor. Her research interests include electrical machinery design, modeling and analysis of electric drives, and control of electric drives.

**Mr. Yuzhe Zhang**

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**Abstract**

Globalization has become one of the hottest topics in electrical engineering education. This paper explores this topic through first-hand experience as a visiting scholar from a Chinese engineering university. First, the engineering education reforming taking place in China will be described by looking at Chinese current EE curriculum requirements. And then, the curricula, semester arrangement, credit and degree systems are compared between Chinese and U.S. electrical engineering undergraduate programs. The emphasis on math, core EE subjects, project design and working experience in industry is stronger in Chinese EE programs comparing to that of U.S. universities. But the tendency of teaching as many core subject courses as possible has resulted in a complete neglect of computer aid and modern tool applications in the curriculum. These differences may have significant long-term impacts on both professional development of electrical engineering students and the educational and technological progress of the countries concerned.

## I Introduction

Globalization has become one of the hottest topics of electrical engineering education. Reference[1] notes, "since education is one of the fundamental strategies to address most global challenges, it is important to identify the most effective educational materials, curricula, and distribution media for global education as well as institutional arrangements to accelerate learning." Electrical Engineering Education of China has been reformed in the past decade to better meet the needs of the ever fast developing electrical industries in China. Especially after Chinese government issued *National long-term Education Reform and Development Plan*, by 2012, fifty universities were approved by Chinese Education Department to carry out the well-known “excellent engineer education and training program” in Electrical Engineering.

In U.S., the electrical engineering is defined as a field of engineering that generally deals with the study of and application of electricity, electronics, and electromagnetism. It covers a wide range of subfields including electronics, digital computers, power engineering, telecommunications, control system, RF engineering, and signal processing [2]. In China, the electrical engineering, also called *Electrical Engineering and Automation*, usually only covers electrical power engineering and electrical machines. The graduates expect to find a job in electrical power industry and related areas.

In China, the electrical engineering curriculum is focused on basic applied math and fundamental engineering sciences. The educational objective is to produce graduates who master solid fundamental engineering theory and are capable of adapting to new technology easily. It is left to the industry to provide the newly hired graduates with trainings on specialized topics. In U.S., electrical engineering curriculum in general adopts a broad educational approach with science, technology, and humanities. Software tools and computer applications are integrated into the curriculum. As the result, U.S. electrical engineering graduates have broader spectrum of knowledge and system level understanding of electrical engineering projects.

Shandong University, where the author has been teaching for more than a decade, will be used as an example to show detailed Chinese electrical engineering curriculum. For general comparison, the authors have chosen the curricula of 40 U.S [3] and 25 Chinese [4] universities as data collecting samples.

Within this context, the aim of this paper is three-fold:
1) Shandong University EE program as an example to represent the reform of Chinese engineering education in the past decade
2) Comparison between U.S. and Chinese EE curriculum in the categories of overall credit requirement for B.S. of EE, engineering core courses, math and basic science, and practical/intern courses
3) Discussion of the underlying rationales, implications and impacts of the differences.

## II. The Electrical Engineering Program at Shandong University

Shandong University is a public comprehensive university and one of the largest universities in China by student population (57,500 full-time students in 2009). It is supported directly by the national government. Electrical Engineering Department of Shandong University was founded in 1932. In 1999, the department developed to Electrical Engineering School. The School now has more than 300 doctoral and master's candidates and 1090 undergraduate students. It has five institutes: Institute of power system, Institute of relay protection, Institute of electrical machinery and electric equipment, Institute of power electronics, and Institute of electrical new theory.

At Shandong University, the undergraduate electrical engineering program is designed to convey up-to-date professional knowledge, as well as to encourage the individual to master the knowledge and skill of electrical engineering [5]. The program has a strong emphasis on mathematics and basic sciences, and the core courses aim to establish a solid fundamental knowledge in all fields of electrical and electronic engineering. In the freshman year, the students are required to study Engineering Graphics which enable students grasp the knowledge and skill of manual and AutoCAD engineering drawing. From the sophomore year to the senior year, students will take a wide range of practical and lab courses which provide students with hands-on experience with electrical engineering. These labs/courses are:

| | |
|---|---|
| electrician foundation lab; | analog electronic technology lab; |
| digital electronic technology lab; | power electronics technology lab; |
| microcomputer lab; | automatic control lab; |
| electrical machine lab; | power system dynamics lab; |

and at least 40 working hours of industrial engineering training in practice factory.

In the second semester of the senior year, students are divided into the following six specialties:

A. Electric Power System
B. Electric Power System Protection
C. Electric Machinery and Apparatus
D. Power Electronics and Electrical Drives
E. High Voltage Technologies
F. Electrical Theory and New Technology.

Every specialty has limited enrollment places and it is a mutual selection process between the instructor and the students. During the senior year, students in different specialties have different required and elective courses. The required courses of each specialty are shown in Table I with every course as 2 credits hours.

Table I the required courses to get a specialty in senior year of electrical engineering at Shandong University

| Specialties | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| **Required Course** | Power Systems Analysis | Power System Protective Relaying | Power Electronics Equipment and Application | Automation Control System for Electrical drive | High Voltage and Insulation Technology | Energy and environment |
| | Auto-control Technology of Power Systems | Power System Protective Relaying | | Micro and Special type Machines | High Voltage and Insulation Technology | Renewable Power Generation |
| | Power System Relay Protection | Power System Automatic Control Technology | Power Electronics Control System | Permanent Magnet Machines | High Voltage Test Techniques | Interconnection and Integration of Electric Power Generation Systems |

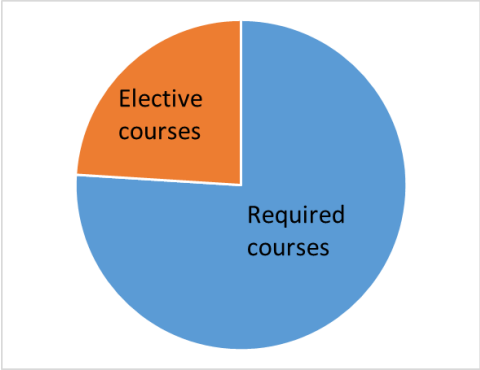
## III. Comparison between U.S. and Chinese B.S. of EE

### *A. Overall Credit Hours*

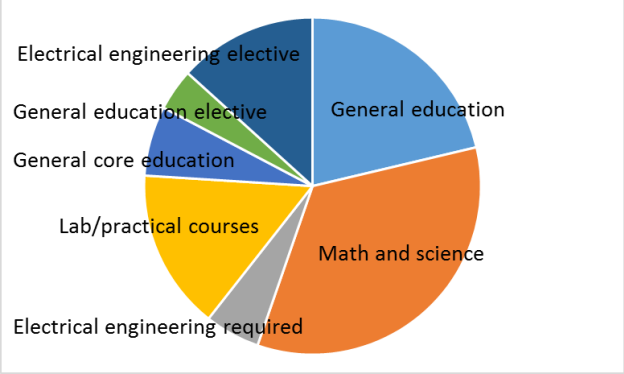
In both Chinese and U.S. universities, the normal duration of the B.S. program is four years. According to the results of a recent questionnaire completed by 125 electrical engineering departments in the United States, the mean number of total credit-hours required for the bachelor of science degree is 133.5 [6]. The range is between 96 and 173, and 92% of the EE departments require between 120 and 140. In contrast, the mean number of total credit hours required for the B.S. degree in Chinese universities is considerably higher as 158.3 with a range between 146 and 196. It is 150 at SDU for electrical engineering B.S. degree with the distribution of credit hours as shown in Table II. Figure 1 displays the pie chart distribution of the courses. The main characteristic of the Chinese electrical engineering undergraduate program is the high number of credit hours allocated to math and technical subjects.

Table II The distribution of credit hours in electrical engineering curriculum at SDU

| Course | | Credit | | Hour | | Percent | |
|---|---|---|---|---|---|---|---|
| **Required courses** | **General education** | 114 | 32 | 1783+26weeks | 771 | 76% | 21.3% |
| | **Mathematics, science and electrical basic** | | 51 | | 872 | | 34% |
| | **Electrical Engineering** | | 8 | | 140 | | 5.3% |
| | **Practical courses** | | 23 | | 26 weeks | | 15.4% |
| **Elective courses** | **General core education** | 36 | 10 | 590 | 160 | 24% | 6.7% |
| | **General education** | | 6 | | 96 | | 4.0% |
| | **Electrical Engineering** | | 20 | | 334 | | 13.3% |
| **sum** | | 150 | | 2373+26weeks | | 100% | |




(a)




(b)

Figure 1. The distribution of credit hours in electrical engineering curriculum at SDU (a) elective versus required and (b) different categories

*B. Engineering Core Courses*

Of the 42 sample U.S. electrical engineering (EE) departments, almost all conform to the ABET requirements, and thus exhibit a uniformity in their programs. With the globalization, Chinese undergraduate engineering programs have been pushed to adopt an "American model" by the government. About 70 Chinese universities have acquired the accreditation of China Experts Committee on Engineering Education Professional Certification. The EE curriculum is set indecently by the school according to its characteristics and the Engineering Education Accreditation (EEA) verifies that weather the contents of four basic categories such as mathematics and natural sciences, engineering-based, professional basis, professional courses meet requirements. The curriculum of each university is determined by the university, but EEA made a provision for the credit hours of the four categories as seen in Table III.

Table III Course requirement of EEA—the adopted "American model" by 70 Chinese universities

| **Courses** | **Mathematics and Science** | **Basic Engineering** | **Basic Electrical Theory** | **Electrical Professional** |
|---|---|---|---|---|
| **Credits Hours** | ≥32 | ≥38 | ≥16 | ≥14 |

In terms of engineering core courses, significant difference can be observed between U.S. and Chinese EE curriculum. The mean number of electrical engineering credit hours of EE courses required by the U.S. universities is 52.9, with a range between 29 and 76. About 79% of the universities which responded to Aspnes's questionnaire required between 46 and 65 credit hours EE course for the B.S. degree [6]. The corresponding mean number of required EE credit-hours at Chinese universities is almost double: 102, with a range between 79 and 166. After the engineering education reforming required by Chinese government, this number decreases for some universities, for example Zejiang University to 84, Xian Jiao Tong University to 89, Shanghai Jiao Tong University to 81. The required number of EE credit-hours at SDU is 82 which is lower than the Chinese mean but well above the US mean.

The freshman EE programs of both U.S. and Chinese universities are mostly dominated by

courses in areas such as mathematics, physics, chemistry and computer programming. In U.S. universities surveyed, approximately 65% of EE departments require no freshman EE courses, 20% require one such course, 9% require two, and about 6% require three [3]. In contrast, the mean credit hours of required freshman EE course in Chinese EE departments is 4.6, far higher than the North American mean of 1.8. Engineering Graphic as an important EE course, nearly is required by all Chinese EE undergraduate programs, but is not seen from the curriculum of US EE departments. The differences become pronounced in the sophomore year, where the mean number of required EE course credit-hours at Chinese universities is 18.2 and only 9.3 at US universities. A comparative overview of some general characteristics of EE programs in China and U.S. universities, and the EE program at SDU is provided in Table IV.

Table IV General comparison of EE courses between U.S. and Chinese EE curriculum

| | **China University** | **SDU** | **US University** |
|---|---|---|---|
| **Total credit hours required** | 158.3 | 150 | 133.5[3] |
| **Total EE credit hours required** | 102 | 82 | 52.9 |
| **First year EE credit hours required** | 4.6 | 6 | 1.8 |
| **Second year EE credit hours required** | 18.2 | 20 | 9.3 |

*B. Mathematics and Basic Sciences*

The mean number of credit hours allocated to mathematics and basic sciences in China and U.S. EE departments is also different. In the U.S., ABET expects the curricular content of the program to include at least one year of mathematics and basic sciences, and one half-year of humanities and social sciences[7]. The mean number of total credit-hours allocated to mathematics, physics, and chemistry in U.S. EE departments is 33.7. The corresponding figure is 25.2 at Chinese universities. It should be pointed out though; the lower number in China is mainly due to the absence of chemistry course in Chinese EE undergraduate programs.

In U.S. EE undergraduate program, the mathematical studies are required to include differential and integral calculus, differential equations, and probability and statistics; additional work is encouraged in one or more of the subjects of linear algebra, numerical analysis, and advanced calculus [7]. Chinese engineering programs are traditionally strong in mathematics, and they generally allocate more courses to this subject in their curricula. The mean number of required mathematics credit-hours for engineering students at Chinese universities is 21, compared to 15 at U.S. universities. Most Chinese EE undergraduate programs require five courses in mathematics—Advanced Mathematics I, Advanced Mathematics II, Linear Algebra, Probability and Mathematics Statistic, Complex Analysis and Integral Transform. Advanced Mathematics I and II include the contents of Calculus I, II and III, Differential Equations, and Numerical Analysis. Table V summaries the percentage of U.S. and Chinese universities that require specific math courses in their EE curricula.

In most U.S. EE programs calculus extend to over three semesters. It usually extends to over two semesters in China and is followed by a course on linear algebra and a course on probability and statistics. In addition, Chinese EE programs require additional courses in mathematics, such as complex analysis, and numerical analysis, which are normally electives in U.S. EE programs.

Table V Percentage of U.S. and Chinese universities that require specific math courses in their EE curricula

| Required Mathematic Courses | US universities | Chinese universities |
|---|---|---|
| **Calculus I** | 6.7% | 84% |
| **Calculus II** | 76.3% | 100% |
| **Calculus III** | 17% | 100% |
| **Linear Algebra** | 25.4% | 100% |
| **Engineering Mathematic** | 27.1% | 100% |
| **Probability and Statistic** | 42.4% | 100% |
| **Differential Equations** | 74.6% | 100% |
| **Numerical Analysis** | 1.7% | 76% |

The most common model for basic science courses adopted by Chinese EE programs is "three/two physics." Most of Chinese EE programs, except for Zhejiang University, do not require chemistry in their curricula. On the other hand, 37.5% of U.S. EE programs include two chemistry courses in their curricula. Instead of chemistry courses, the computer science courses are required in the curriculum of Chinese EE departments during the freshmen year. Foundation of Computer and C /C++ Program Designing is the two most popular ones required. As of physics, 100% of Chinese EE programs include two, and 55.7% include three physics courses in their curricula while the corresponding percentage for U.S. EE programs are 22.5% and 45.5%, respectively.

*C. Practice Courses/internship*

U.S. universities always encourage and assist students to get internship. But the internship is rarely officially included in the curriculum. Most U.S. EE students have interns in the summer. Schools may have record of whether or not the student gets interns in EE professional field and how long the interns last. But internship is not one of the requirements for B.S. degree. In China, most EE programs develop and manage practice courses to give all students a chance to work in a controlled real-life industry environment. These courses are focused on industrial practice and applications. Most Chinese universities have built up their own engineering training center (or shop) to provide professional technicians and complete advanced equipments for students training.

Take SDU for example; there are five practice courses in its EE curriculum:

1. A 3 credits metal - engineering practice course in sophomore first semester. EE students work in the engineering training center for 120 hours to be familiar with the mechanical machining process and operations. They need to complete several assignments including turning, boring, metal pouching, milling, and metal heat treatment.
2. A 3 credits EE practice course in sophomore second semester. Students spend 2 weeks the engineering training center to produce electronic products, such as a mini-radio. The knowledge of circuits and electronics would be well applied in this practice course.
3. A one week cognition practice course before taking the electrical machinery course. The content is generally plant tours to the local electrical machine and transformer manufactures facilities.
4. A 6 credits four-week production practice course in the summer before senior year. Students work in local power plants as interns and are directly involved in the production

process. This course gives students an excellent opportunity to apply knowledge learn to the real working environment in Chinese power industry while learning new things in the areas of actual production process and project management.

5. A 16 credits 16-week senior capstone practice course. Students spend 16 weeks working as interns in engineering firms and solve well-defined engineering problems. In general, students also spend the last semester of their senior year working on their diploma thesis at the same firms. This practice course arrangement has also yield competitive job offers for many students.

These five practice courses are linked with each other and provide students with experience at different level. Although it means a lot of planning work for the instructor and the department, rewarding results are the drive to keep these courses alive and thrive.

## IV. Discussion and Conclusions

Chinese industries expect engineering graduates to have the current know-how to solve immediate problems. This expectation is generally reflected in university curricula in which there are a tendency to teach as many courses as possible in the core subject. As a result, the total credit-hour requirement is considerably higher than that of U.S. universities. One of the results of squeezing too many subject matter courses into the curriculum is a complete neglect of computer aid tool applications. In reality, most Chinese EE students have never used MATLAB /Simulink before their senior year.

Chinese EE programs put stronger emphasis on mathematics and EE core courses than U.S. EE programs. Meantime, Chinese EE program has weaker physics requirements and no chemistry requirement at all. This echoes to the definitions differences in electrical engineering with broader knowledge spectrum in U.S. and specialization focused in China.

The practice courses/interns as a mandatory requirement of B.S. EE degree in China shows promising outcomes of training electrical engineers who can take on real-life industry projects right after graduation.

Table VI Freshmen enrollment of EE undergraduate program at SDU

| Academic Year | Total freshmen | Male freshmen | Female freshmen | |
|---|---|---|---|---|
| | | | Number | Percent of Whole |
| 2013 | 196 | 159 | 37 | 18.88% |
| 2012 | 192 | 161 | 31 | 16.14% |
| 2011 | 203 | 168 | 35 | 17.24% |
| 2010 | 242 | 203 | 39 | 16.11% |
| 2009 | 238 | 196 | 42 | 17.64% |

Another note which may not be exactly the focus of this paper but worth mentioning is that with rapid development of electrical industry in China, a broad range of employment and competitive salary have promoted the freshmen enrollment of electrical engineering students. By the end of 2013, there are 367 universities offering the electrical engineering undergraduate program. It needs to be pointed out that these EE programs only devote to power engineering as explained in the introduction section. The EE freshmen enrollment number in 2013 is more than 50,000[8]. Similar to what happens with U.S. EE program, the percentage of female students is low ranging

from 10% to 20% which is much lower than that (51.03%) of whole undergraduates reported by Ministry of Education Department of China [9]. Yet, due to the large EE students base in China, this low percentage still be able to yield relatively large number of female EE students in freshman. As an example, Table VI shows the freshmen enrollment of EE program students in SDU for the past 5 years.

Chinese engineering programs put much emphasis on technical skills yet seem the communication skills, leadership skills and humanity related skill are missing. Although a curriculum would represent an academic idealization of real-world needs on some level, engineering education in a technologically developing country is often based on a narrow, functionalist view of the engineer's role in society. The fact that universities can only graduate potential "engineers," who will earn this title by their contribution to society, is often overlooked. In the context of globalization, the humanities and social sciences constitute the vital, human component of engineering education, which enables teamwork, interpersonal relationships, and international, intercultural communication [9]. "In terms of graduation, it is often the technology-based courses that help the students get the first job, the science course that helps them keep it five years out, and the social science and humanities courses that help them move up into top management" [10] It is clear that differences of Chinese and US EE undergraduate programs may have significant long-term implications, in the context of globalization, for both the personal development of electrical engineers and the educational and technological progress of the countries concerned.

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## REFERENCES

[1]. J. e. Glenn and TJ. Gordon, State of the Future: Executive Summary. Millennium Project, American Council for the United Nations University, New York, 2006.

[2]. http://en.wikipedia.org/wiki/Electrical_engineering

[3]. See the web pages of the following universities: See the web pages of the following universities: Alabama University, Boston University, Bradley University, California State University Chico, California State University Fresno, University of Central Florida University, University of Colorado Boulder , Colorado State University, Dayton University, University of Denver, University of Florida, Florida Atlantic University, Gannon University, The George Washington University, Georgia Institute of Technology, University of Hartford, The University of Iowa, Kansas State University, University of Maryland, University of Michigan, Michigan State University, Michigan Technological University, University of Mississippi, Mississippi State University, University of New Hampshire, University of New Mexico, New Mexico State University, New Mexico Institute of Mining and Technology, University of New Orleans, University of North Dakota, Ohio State University, Penn State University, Rutgers University, University of South Carolina, Stanford University, The University of Texas at Austin, Villanova University, Wayne State University, The University of Wisconsin, Wright State University, These web pages were visited during the period Sep. 15, 2013–Oct. 15, 2013.

[4]. See the web pages of the following universities: Beijing JiaoTong University, China University of Mining Technology, North China Electric Power University, Chongqing University, Guangzhou University of Technology, Harbin Engineering University, Harbin Institute University of Technology, Harbin University of Science and Technology, Hehai University, Huazhong University of Science and Technology, Nanjing University of Aeronautics and Astronautics, Northwest Polytechnic University,

Shandong University, Shanghai Jiao Tong University, Shenyang University of Technology, Sichuan University, South China University of Technology, Southeast University, Southwest Jiao Tong University, Xian Jiao Tong University, Tianjin University, Tsinghua University ,Wuhan University, Zhejiang University, Zhengzhou University.(in Chinese)
[5]. Chinese Ministry of Education, China Long-term Talent Development Plan (2010-2020), 2010.06 (in Chinese )
[6]. J. Aspnes, A summary and analysis of bachelor of science degree requirements reported by 125 electrical engineering departments, IEEE Trans. Educ., vol. 37, no. 2, pp. 122–130, 1994.
[7]. Accreditation Board for Engineering and Technology, Criteria for Accrediting Programs in Engineering in the United States. New York:ABET, 1997.
[8]. http://www.gdzsxx.com/gaokao/jy/201306/40275.html
[9]. http://www.moe.gov.cn/publicfiles/business/htmlfiles/moe/s7567/201309/156890.html
[10]. Ron Hira, Engineering Globalization: Implications for Engineering Education, Microwave Symposium Digest (MTT), 2012 IEEE MTT-S International 2012 , pp: 1 - 3
[11]. F. Barnes, New challenges for engineering education, IEEE Trans. Educ., vol. 37, pp. 119–121, 1994.