Comparison of Engineering Honors Education in America and China—Based on the Analysis of Course Syllabi in the First-year Program and Experimental Class

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Abstract

Honors Education, known as education for high-achieving students, originated from the "Pass/Honors Examination" of Oxford University in the 19th century and has a history of over 100 years. With the goal of providing specialized and personalized education for gifted undergraduates, honors education has played an important role in the cultivation of excellent students. Through literature review and on-site observation, it was found that many variations of honors programs have been developed for engineering students, including Honors Programs, Scholars Programs, and the Engineering Experimental Classes. These honors programs for engineering students are called "engineering honors education/programs" in this paper.

Previous research on the introduction, practice, experience and assessment of engineering honors programs has provided a foundation for this study. However, growing international cooperation and competition has increased the globalization of engineering. Students need to understand differences and similarities in the diversified engineering educational systems. In addition, administrators and faculty also need to understand these differences and potentially make improvements in curriculum based on these findings. Therefore, this paper takes the First-year Engineering Honors Program at the Ohio State University in the United States and the Engineering Experimental Class at Beihang University in China as their case studies of international comparison of the entire first two years' curriculum. As an intermediary of teaching activities and the basic guarantee of achieving educational goals, course is a blueprint and plan for cultivating what types of people. This paper takes courses as the research object, compares the whole course setting, and studies the syllabi of basic courses and teaching methods reflected in the syllabi. Methodologies including text analysis, frequency analysis, comparative research and keywords extraction are being used to collect and analyze the keywords extracted from the course learning objectives, topics and outcomes in the course syllabi. Tools used for these analyses include Excel2016 and ywordle2.0.

By comparative study, the similarities, differences and features of engineering honors education in both countries are revealed. On the whole, the course categories for each academic year in both programs are the same, which reflects the course setting of current engineering education and even engineering honors education. As for the basic courses (mathematics, physics, chemistry and life science), both programs focus on the students' understanding of the basic concepts, principles and knowledge of the subject, as well as the abilities to utilize the concepts and principles to solve problems. However, the numbers and categories of basic courses offered by the Experimental Class in China exceed those of the First-year Engineering Honors Program, indicating more emphasis on basic subject teaching in Chinese engineering education. The American program focuses more on basic engineering education, and has specifically set up ENGR1281 and ENGR1282 to improve the retention rate in engineering. Moreover, the honors program in America places more emphasis on students' practical ability, capacity to solve practical problems, as well as an emphasis on teamwork abilities. Through hands-on lab experiences and project-based experimental design, students are able to experience the real engineering environment.

Keywords: Engineering Honors Education, First-year Engineering Honors Program, Engineering Experimental Class, Comparative Analysis, Courses Syllabi Analysis, Keywords Extraction

Introduction

Honors Education, known as education for high-achieving students, originated from the "Pass/Honors Examination" of Oxford University in the 19th century and has a history of over 100 years. With the goal of providing specialized and personalized education for gifted undergraduates, honors education has played an important role in the cultivation of excellent students. Furthermore, as Jame J. Clauss proposed "Shouldn't we aspire to this goal for all university and college students?" in the paper "The Benefits of Honors Education for All College Student" [1], honors education not only has a particular function to develop top or outstanding students, but also has special significance for the entire undergraduate education [2]. In the 1920s, Frank Aydelotte Project which was founded at Swarthmore College by Frank Aydelotte - the founder of Honors Education in the United States, was considered the first blueprint for modern honors education in American colleges and universities [3]. Influenced by it, many other U.S. colleges and universities began to set up honors projects. Honors education in China was originated in the 1970s. Although relatively late, it has attracted the great attention by the state and universities. Through literature review and on-site observation, it was found that many variations of honors programs have been developed, including Honors Programs, Scholars Programs, Honors and Experimental College, Experimental Classes and Freshman Seminar Program [3], which are also conducted in engineering education. These honors programs for engineering students are called "engineering honors education/programs" in this paper.

Previous research on the introduction, practice, experience, assessment and comparisons of engineering honors programs has provided a foundation for this study [4], [5], [6]. Comparative studies of engineering honors education focus on the horizontal comparison between honors items and non-honors items [7], as well as the vertical comparison within engineering honors programs [8]. However, growing international cooperation and competition has increased the globalization of engineering. Students need to understand differences and similarities in the diversified engineering educational systems. In addition, administrators and faculty also need to understand these differences and potentially make improvements in curriculum based on these findings. Therefore, this paper takes the First-year Engineering Honors Program (FEH, for short) at the Ohio State University (OSU, for short) in the United States and the Engineering Experimental Class (EEC, for short) at Beihang University (BUAA, for short) in China as their case studies of international comparison. All required courses in the first-year programs are included in the study. Both programs have very selective admission criteria and provide excellent and personalized education for the selected outstanding students. As an intermediary of teaching activities and the basic guarantee of achieving educational goals, course is a blueprint and plan for cultivating what types of people [9]. Therefore, this paper takes courses as the research object, compares the whole course setting, and studies the syllabi of basic courses and teaching methods reflected in the syllabi. By means of extracting keywords, the similarities and differences between the two programs are analyzed in terms of learning objectives, topics, outcomes and teaching methods that are reflected in the syllabi.

Methodology

The curriculum of FEH and EEC for four years were collected (as shown in Table1). Both programs have very selective admission criteria and the same training track. Outstanding students gain access to the programs through the admissions selection process. After one year of basic courses and general education courses, they begin to study in a specific engineering major in the second academic year. In the next two years, students mainly study professional courses and general courses. Due to the large differences in professional courses of different majors, this paper mainly explores the overall situation through case studies, which mainly focuses on the course setup and course contents of the first two years.

Table1. All Curriculum of Engineering Honors Education in FEH and EEC

Time	Courses Titles（FEH）	Courses Titles（EEC）
The first academic year	MATH 1161 MATH 2162	Advanced Algebra 1 Advanced Algebra 2
	PHYSICS 1260 PHYSICS 1261	Mathematical Analysis 1 Mathematical Analysis 2
	ENGR 1281 ENGR 1282	Basic Chemistry 1 Basic Chemistry 2
	ENGR 1100	College English 1 College English 2
	General Education	Advanced Language Program Design
		Basic Physics 1
		Introduction of Life Science
		Lectures on Integrated Frontiers of Discipline 1 Lectures on Integrated Frontiers of Discipline 2
		General Courses
The second academic year	MATH 2568 MATH 2415	Basic Chemistry Experiment
	CHEM 1250	Mathematical Analysis 3
	STAT 3450	ODE
	ISE 2040	Basic Physics 2
	MATSCEN 2010	Basic Physics Experiment 1 Basic Physics Experiment 2
	Professional Courses	Mathematical Modeling
	General Education	Probability and Statistics
		General Courses
		Professional courses：Core Courses and Elective Courses
The third academic year	General Education	General Courses
	Professional Courses	Professional Courses
The fourth academic year	General Education	General Courses
	Professional courses	Professional Courses

As a contact between the students and professors regarding course expectations and policies [10], course syllabi play an important role in presenting the course contents and ensuring the teaching quality. The curriculum syllabi for all compulsory courses in the first and second year of both projects are collected. For better comparison and analysis, the method of keyword extraction is adopted in the text analysis of the syllabi. Only notional words were extracted from the learning objectives, topics and outcomes in the curriculum syllabi.

The frequency and weight of keywords are calculated through Excel2016. Developing a word cloud map by ywordle2.0 based on the statistical results will help to clearly present the contrast. The size, location and number of keywords in the word cloud map reflect the importance of the keywords.

Results and Discussions

Holistic Comparative Analysis of Honors Courses between FEH and EEC

The common grounds of course planning in the two programs are as follows: setting the basic courses and general education courses in the first academic year; the basic courses, general education courses and professional courses in the second academic year; professional courses and general courses in the third and fourth academic years. Though the number of EEC courses presented in Table 1 is far more than that of FEH courses, the total remaining credits are basically the same after removing the credits of courses (courses related to ideological and political education and English) specially offered by Chinese universities. The same course categories and a similar number of credits indicate that the workload of students in honors education programs of China and America are about the same.

Table 2. Course Categories of Engineering Honors Education in FEH and EEC

Time	**Courses Titles （FEH）**	**Courses Titles（EEC）**
The first academic year	***Foundation Courses***	***Foundation Courses***
	General Courses	General Courses
The second academic year	***Foundation Courses***	***Foundation Courses***
	General Courses	General Courses
	Professional Courses	Professional courses
The third academic year	General Courses	General Courses
	Professional Courses	Professional Courses
The fourth academic year	General Courses	General Courses
	Professional Courses	Professional Courses

In terms of the specific course type, since the students start to choose specific professional courses in the second academic year (by declaring a major of study), the specialized courses differ from one professional to another and therefore are not comparable. Nonetheless, the basic courses teaching, as the most foundational teaching work in colleges and universities, is the most important link of teaching basic knowledge and theories and cultivating students' study abilities in the process of talent cultivation [11]. It is also a significant teaching task emphasized by colleges and universities.

From Table 1, the basic courses in FEH include MATH1161, MATH2162, MATH2568, MATH2415, STAT3450, PHYSICS1260, PHYSICS1261, CHEM1250, ENGR1281, and ENGR1282. And basic courses including Advanced Algebra 1, Advanced Algebra 2, Mathematical Analysis 1, Mathematical Analysis 2, Mathematical Analysis 3, Mathematical Modeling, Probability and Statistics, ODE, Basic Physics 1, Basic Physics 2, Basic Physics Experiment 1, Basic Physics Experiment 2, Basic Chemistry 1, Basic Chemistry 2, Basic Chemistry Experiment, Introduction of Life Science, Advanced Language Program Design (ALPD, for short), are offered in EEC. By contrast, math, physics and chemistry courses are offered by both American and Chinese universities; ENGR1281 and ENGR1282 are FEH-specific foundational courses; and Life Science and ALPD are unique to EEC. However, based on the analysis of the topics in the syllabi, it shows that in ENGR1281, in addition to introducing the basic method of solving engineering problems, one third of the content is MATLAB and one third teaches C / C ++, which is basically consistent with the ALPD course in EEC; and ENGR1282 mainly teaches engineering graphics, visualization, and engineering design. In terms of the number of courses, EEC's overall number of math, physics and chemistry courses is more than that of FEH. This explains to a certain extent that EEC pays more attention to basic subject teaching.

Furthermore, the comparison of course syllabi indicates that all FEH courses depend on the Canvas learning management system, allowing teachers to post any information related to the course, collect student assignments, give student feedback, grading, etc. In addition, a flipped classroom environment is achieved through Canvas by posting preparatory work and videos for students to complete prior to class. These are not found in the syllabi of EEC.

To further compare similarities and differences in basic courses, in the next section, ENGR1282 in FEH program and Introduction of Life Science in EEC will be first introduced, and then math, physics, and chemistry courses will be compared by analyzing the syllabi.

ENGR1282（FEH）and Introduction of Life Science（EEC）

Engineering 1282 is the second course in the fundamentals of engineering sequence and includes engineering graphics, visualization, and engineering design. During the graphics portion of the term, the class session will have a brief presentation followed by in-class studio time. For the design portion, the class will consist largely of hands-on time and focus primarily on the planning, management, execution, documentation, and presentation of the FEH design project. The purpose of this sequence is to build students' knowledge of engineering fundamentals, including engineering graphics, communication, problem solving, the design process, and experiences in a hands-on laboratory. The goal is to develop a strong foundation for both students' future academic work and professional career. Successful students will be able to do the following: produce engineering drawings and models both by hand and using the SolidWorks CAD package, visualize objects in three dimensions, work in teams to perform various elements of engineering design, and demonstrate effective technical communication skills. In the syllabus, "Engineering design is more than just tinkering; it is the logical application of scientific principles to a tangible design. It involves creativity, dedication, thought, research, ingenuity, and work. It may well be your first experience in "real world" engineering." are put special emphasis. According to the topics, objectives and teaching methods in the syllabi, it can be seen that ENGR1282 emphasizes project-based learning and focuses on cultivating students' engineering fundamentals, hands-on skills, creativity, practical ability and thinking ability. This is also reflected in the teaching goal of ENGR1281 and its weekly experimental class project.

In the EEC curriculum, the topics of Introduction of Life Science include outline of life science, cells and cell engineering, gene engineering, synthetic biology, protein structure and function, microbial and virus, regenerative medicine, cancer, the bible and brain science, biological chips and high-throughput sequencing technologies, evolution and bionics. The course study helps students to understand and grasp the basic concepts and knowledge of life science, basic rules of life activities; to understand the basic research methods and thinking modes of life science; to learn the whole picture and new trends of life science development, as well as the inevitable trend of the integration for modern life sciences and other subjects; to understand and preliminary utilize biological principles, ideas, ways of thinking to recognize some of the phenomena and processes of life. Students are required to be equipped with basic life science literacy, master fundamental life science knowledge, and learn to make use of basic life science research methods and thinking mode knowledge to solve problems. By improving students' knowledge system and cultivating innovative ideas with multidisciplinary, it lays the foundation for further study. Although biological science is an experimental science, there is no corresponding experimental class. During the class, a variety of experimental apparatus and experimental displays are provided, and some of the technical content of experiments are provided by means of videos to more tangibly present experiments to the students. Obviously, the course emphasizes more on the basic theoretical knowledge and multidisciplinary ideas, but lacks the practice link. Therefore it's strong in theory and weak in practice.

Comparative Analysis of Mathematics Courses

This paper combines the mathematics courses of the two programs and conducts the overall comparative analysis. Mathematics courses in FEH with 18 credits include: MATH1161(Accelerated Calculus1), with 5 credits; MATH2162(Accelerated Calculus2), with 5 credits; MATH2568(Linear Algebra), with 3 credits; MATH2415(Differential Equations), with 3 credits; STAT3450(Stat Meth), with 2 credits. EEC offers 34-credits mathematics courses, including Advanced Algebra 1 (5 credits), Advanced Algebra 2 (5 credits)， Mathematical Analysis 1 (5 credits), Mathematical Analysis 2 (5 credits), Mathematical Analysis 3 (5 credits), Mathematical Modeling (3 credits), Probability and Statistics (3 credits), ODE (3 credits). According to both the number of credits and courses, EEC has richer courses and content, covering more knowledge concepts. Although the FEH mathematics courses are relatively fewer than those of China, it far exceeds the number of hours and courses offered by physics and chemistry in the program. It indicates that both programs greatly emphasize math-based course teaching.

In terms of the teaching form, as mathematics courses are centered on basic knowledge, there is no experimental class and all are theoretical courses. This is one of the similarities between the two programs, but different from physics and chemistry courses.

The keywords are extracted from the course description, objectives and outcomes in the syllabi. Because there are far more courses in EEC than in FEH, the number of keywords extracted from the EEC courses syllabi is larger, with higher frequency and weight. However, the comparison shows that in both programs, the keywords with high frequency are "understand basic concepts/theory/principle", "use to solve problem", "comprehend methods", "develop skills", "apply", "recognize importance", "computational skill", "logical reasoning ability", "independent thinking ability", "mathematical modeling ability", etc. Based on the similarities, the keywords from both programs are presented in the same word cloud map (as shown in Figure 1). In addition, in the course syllabus of EEC, "laying the mathematical foundation for follow-up courses" appears many times. On the one hand, it shows the importance of mathematics as a basic discipline; on the other hand, it indicates that

Chinese colleges and universities attach the importance to mathematics courses.

Figure 1. Word Cloud Map of Keywords extracted from Mathematics Syllabi

Comparative Analysis of Physics Courses

This paper combines the physics courses of the two programs and conducts the overall comparative analysis. FEH sets two physics courses with 10 credits, including PHYSICS1260 (5 credits) and PHYSICS1261 (5 credits). Total 14-credits physics courses in EEC contains Basic Physics 1 (5 credits), Basic Physics 2 (5 credits), Basic Physics Experiment 1 (2 credits) and Basic Physics Experiment 2 (2 credits). By comparison, it's found that theoretical courses and experimental courses in FEH are included in the same course. Theoretical courses are usually taught 1 to 4 times a week and experimental courses are taught one time a week (except for special cases). The contents of experimental course and theoretical course are basically corresponding. The former develops students' ability to solve practical problems mainly through project-based learning. However, in EEC, the contents of experimental course and theoretical course are independent. Therefore, from the perspectives of credits and course setting, the number and structure of physics courses in both projects are basically the same. By extracting and comparing the keywords in the topics of syllabi, it's found that in the theoretical course section, the main headings are almost the same; to be more specific, as for each subheading, the EEC courses contain more contents and details.

The comparative analysis of keywords extracted from teaching objectives and outcomes shows that FEH physics courses emphasize on "understanding principles, theories and methods of modern science", "understanding the relationship between science and technology", "understanding the significance of scientific discovery", "recognizing the social and philosophical implications of science discovery" and "understanding the potential of science and technology to solve the problems of the contemporary world". In addition, it cultivates students' practical ability and the ability to solve the practical problems through the "written solution" part in the homework and the group problem solving activities specifically designed in the experimental courses. EEC's physics courses emphasize "understanding the concept of physics", "correctly understanding basic concepts, theories and methods", "enhancing the ability to analyze and solve problems", "cultivating the spirit of exploration and innovation", and "laying the foundation for further study"; its experimental courses focus on "acquiring knowledge and understanding theories through observation and analysis measurement methods", "cultivating the ability of innovation and practice", "cultivating the skills of scientific experiments" and "laying the foundation for subsequent courses and work". According to the contrast, both the two programs emphasize on helping students master the basic concepts, theories and methods of the physics subject and cultivating students' practical abilities. However, the courses of FEH pay more attention to students' abilities of using knowledge to solve practical problems. EEC physics courses emphasizes more on the contribution of Basic Physics and Basic Physics Experiment as basic courses to future courses and work.

Comparative Analysis of Chemistry Courses

This paper combines the chemistry courses of the two programs and conducts the overall comparative analysis. There is only one chemistry course-CHEM1250 in FEH with 4 credits. EEC offers 10-credits chemistry courses, including Basic Chemistry 1 (3 credits), Basic Chemistry 2 (3 credits), Basic Chemistry Experiment (4 credits). Similar to FEH physics courses, chemistry course in FEH consists of the theory part and experimental part. Students are required to attend a 2-hour and 55-minute experimental class weekly and write up an experimental report. The experimental class accounts for 20% of the course grade. In order to pass the exam of this course, students have to gain more than 50% of the grade points in the experimental class. In other words, if the experimental grade is less than 50%, the students cannot pass the course even if they get full marks for the remaining 80%, which demonstrates the importance of the experimental part. In contrast, the EEC chemistry courses are still divided into three separate courses: two theoretical courses and one experimental course, which are opened in different semesters. Through the comparison of the keywords of topics in the syllabi, it is found that the contents of EEC courses are relatively rich and specific, because of the difference between the number of courses and the credits.

The comparative analysis of keywords extracted from teaching objectives and outcomes present that FEH chemistry courses emphasize on "understanding basic facts, principles, theories and methods", "understanding key events in scientific development" and "recognizing that science is the subject of continuous knowledge development" , "being able to describe the interdependence of technological development", "recognizing the social and philosophical implications of scientific development" and "understanding the potential of science and technology to solve the problems of the contemporary world". It can be seen that they are basically the same as the focuses in physics courses of the program. To a certain extent, it shows the common goal of basic courses. EEC chemistry courses emphasize on "understanding basic principles and knowledge", "understanding basic theories and basic concepts", "understanding the application of these theoretical knowledge and skills in engineering practice", "developing problem-finding and problem-solving skills", and "laying the foundation for further study"; in terms of experimental courses, it focuses on "the practical application of basic knowledge and theories", "training experimental ability" and "training experimental design ability". By contrast, it's found that whether FEH or EEC, chemistry courses, similar to mathematics and physics courses, still pay attention to the understanding and application of basic knowledge, concepts, principles.

Conclusions

Through the comparison of course settings, course categories, syllabi, course objectives, and course outcomes in FEH and EEC, there are many similarities. On the whole, the course categories for each academic year in both programs are the same, which also reflects the course setting of current engineering education and even engineering honors education. Basic courses and general education courses are offered in the first academic year, with basic courses, general education courses and professional courses in the second academic year; and professional courses and general courses in the third and fourth academic years. As for the training objectives of the basic courses(mathematics, physics, chemistry and life science), both programs focus on the students' understanding of the basic concepts, principles and knowledge of the subject, as well as the ability to utilize the concepts and principles to solve the problems. This is in line with the attributes of mathematics, physics, chemistry and life science as the basic disciplines and also reflects the importance and recognition degree of basic disciplines.

According to comparative analysis, the differences between the two programs in the course setting, syllabi and teaching methods also reflect the respective characteristics of the two. Firstly, the number and categories of basic courses offered by EEC are more than those of FEH, indicating China's emphasis on basic subject teaching in engineering education, so as to help students obtain solid basic knowledge. Secondly, FEH focuses more on basic engineering education. ENGR1281 and ENGR1282 have been specially set up with diverse topics and laboratories providing a broad overview of engineering disciplines to enable students to understand and choose an engineering major. Relevant research also proved the improvement of retention rates in engineering [12]. Thirdly, FEH courses place more emphasis on students' practical ability, capability to solve practical problems, as well as teamwork skills. All the ENGR and the physics and chemistry courses have corresponding experimental parts. Hands-on lab experience about once a week, is designed to give students exposure to a variety of engineering disciplines, as well as to teach them how to use particular tools, employ some data techniques, and write technically [13]. Besides project-based experimental design, honors students can also engage in a more challenging and substantial design project [14]. Through all of these activities, students are able to experience the real engineering environment.

With the acceleration of economic globalization and the international cooperation of engineering activities, the internationalization of engineering education is imperative. Engineering education will face more opportunities and challenges. It is the future direction of engineering education to cultivate engineering talents who meet international needs and possess a solid basic knowledge, innovative spirit, strong creativity and practical abilities through international and inter-school exchange and reference. Combined with the above research, the authors look forward to the future research based on this initial study. On the one hand, the professional course materials of the two programs can be further collected, to explore the similarities and differences of specific engineering specialty teaching by taking the professional courses as the research object. On the other hand, through the refinement of indicators and follow-up surveys, further comparisons on basic knowledge and practical abilities can be made between the students in the two programs.

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