Comparison of Chemical Engineering Undergraduate Curriculum of Universities in China and Ethiopia

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Abstract

In this paper, a comparative evaluation of the undergraduate program of Chemical Engineering curriculums of Chinese and Ethiopian universities was performed. The study employed systematic qualitative methods to synthesize the current qualitative researches into an explanatory process. To comprehend the Chemical Engineering curriculum structure in two countries, a survey of courses from each country institution is presented. Since both countries use harmonized chemical engineering curriculum with their respective institution, top university from each country was taken as a representative sample, Tsinghua University (THU) from China and Addis Ababa University (AAU) from Ethiopia. The major aspects in the comparison were the lengths of the programs, measurement of student workload, practical curriculum, and the ratio of general, core, compulsory and non-compulsory courses. At the THU, the minimum length for the undergraduate program is 4 years, whereas at AAU a minimum of 5 years is expected. While general education courses occupy 70% of the total credit in the THU curriculum showing more emphasis on general courses, the AAU curriculum gives more focus to core courses by allocating 70% of its total credit. The THU curriculum proves to be more flexible, offering more elective courses at different stages of the program; the AAU curriculum has provided the chance for a range of specialty streams offering elective courses in the final year of the program. Thus, it is highly appreciable for both countries' universities to optimistically add more courses to their present curriculum based on their socio-economic trait, cultural backgrounds, national demands, and resource availabilities.

Keywords: chemical engineering, curriculum comparison, China, Ethiopia

1. Introduction

Chemical engineers assist in the management of resources, the protection of the environment and the regulation of health and safety practices, etc. Almost all goods and services that modern society relies on is the work and products of chemical engineers. Currently, vast numbers of universities are establishing chemical engineering programs to satisfy the demand for chemical engineers in their respective countries. However, countries are designing their curriculum solely based on the need and demands of their local market; it will be difficult for graduates to be competitive in the global market. A comparative assessment of different countries' practices provides an opportunity to explore and share different experiences for the benefit of strengthening the merits and rectifying drawbacks of one curriculum; it helps to be competitive in the global market. So, this paper is aimed to assess the two countries' chemical engineering curriculum, which are economically, geographically, culturally, etc. distinct nations, China and Ethiopian.

According to Dong and Liu (2016), chemical engineering education in China was introduced by a group of pioneers trained in Western countries with the educational methodology of unit operations in the early 1920s and then with that of transport phenomena in the 1950s. With continuous reforming, the current paradigm of chemical engineering attains. The quick development of the chemical industry in China is driving the growth of China's chemical engineering education and research, both in terms of size and quality (Jin & Cheng, 2011). Since 1998, China has combined almost all bachelor programs related to the chemical industry and unanimously classified them as "chemical engineering and technology" (Wang & Pan, 2016). The total number of chemical engineering departments

in China is more than 360 and over 30,000 undergraduate students a year are studying chemical engineering (Zhao, 2017).

Based on QS World University Ranking (Quacquarelli Symonds, 2020), Tsinghua University (THU) is that the prime best university in China and the fifteenth in the world. THU is a well-known Chinese university that's directly associated with the Ministry of Education. It's a number one center for instruction and science analysis and is known as a key University in each National project 985 and 211(THU Programs for International Studies, 2020). The establishment was originally in 1911 beneath the name Tsinghua faculty. THU is that the prime eleven universities within the world and graded first in Chinese Universities within the field of chemical engineering (THU Programs International Studies, 2020). Currently, the THU offers 82 undergraduate programs with a total of 16,287 full-time undergraduate students (Tsinghua University, 2020). The department of chemical engineering of THU, which is known for its notable alumni like the current General Secretary of the Communist Party of China and Chairman of China, Xi Jinping, was established in 1946. The department is aimed at cultivating high-level and high-quality technological and managerial talent with a solid foundation of knowledge, plus the strong practical ability and creative thinking in basic chemical engineering and related fields. Currently, 480 full-time students are enrolled in an undergraduate chemical engineering program at the department (Tsinghua University, 2021).

On the other hand, Addis Ababa University (AAU) is a public higher education institution established in the capital city of Ethiopia in East Africa. According to Best Global University rankings (US news, 2021), Addis Ababa University (AAU) is top 10 universities in Africa and the top 1st in Ethiopia. Ethiopia's oldest and largest higher learning and research institution, Addis Ababa University (AAU), was established in 1950 as the University College of Addis Ababa (UCAA). AAU has risen from 33 undergraduate students in 1950 to 29,872 undergraduate students today. The university currently has ten schools, four institutes that teach and study, and six research institutes that primarily conduct research. There are 55 departments, 12 centers, 12 colleges, and two teaching hospitals within this academic unit (Addis Ababa University, 2021). Chemical engineering education is one of the newest science-based engineering educations to be implemented in Ethiopia, intending to promote the country's socio-economic growth by reducing skilled labor shortages and pushing the chemical industry to adopt cutting-edge technologies. From 1981 to 1986, it was part of a minor program in the department of mechanical engineering at AAU. In 1986, Bahir Dar University launched a fully-fledged Chemical Engineering Department with a program leading to a Bachelor of Science Degree after five years of intensive preparation with four goals: teaching, consulting, and technical services. More than 18 universities have already started offering chemical engineering as an undergraduate program in the country (Ethiopian Ministry of Education, 2013).

This paper aimed to provide useful information for the advancement of chemical engineering undergraduate education by comparison of the undergraduate chemical engineering curriculum of THU and AAU from China and Ethiopia respectively.

2. Methodology

Secondary data sources were used in this investigation. A detailed systematic review of the various types of literature was conducted. Secondary data sources for this study include (i) reports, (ii) journals, (iii) search engines. (iv) scholarly articles and company websites, and (v) other academic publications. Qualitative analysts are encouraged to identify a set of primary research studies and to change them into categories (Levitt, 2018). The comparative analysis is based on a model consisting of the definition, explanation, and simultaneous comparison (Bereday, 1964). In a comparative analysis, elements for comparison must have differences and similarities for the study to be valid (Ragin, 1987). Establishing the parameters for the initial comparability of the chosen units of analysis is a precondition for each comparative investigation (Bray et al., 2014). Similarly, this review employs systematic qualitative methods to synthesize the current qualitative researches into an explanatory process to build greater sense.

2.1 Sample Selection

According to Wang & Qian (2016), China harmonized all chemical engineering and technology undergraduate programs, with very similar course modules and contents included in the curriculum. Similarly, Ethiopia has harmonized the chemical engineering undergraduate curriculum in 2013 to improve the mobility of students and guarantee a common standard of education throughout the country (Ethiopian Ministry of Education, 2013). One university from each country, which is THU from China and AAU from Ethiopia, was selected for comparison. Both THU and AAU are among the best universities in their respective country, and they are also pioneers in the field of chemical engineering education with outstanding teaching achievements, and their teaching achievements are

overwhelmingly representative. Therefore, the undergraduate chemical engineering program curriculums of THU of China and AAU of Ethiopia are selected as a representative curriculum for this comparative study.

3. Result and Discussion

3.1 Length of Program, Credit Systems, and Minimum Allowed Credit Hours (CH)

3.1.1 Length of Program

The first aspect taken into account in the comparison is the difference in the minimum length of time required for the program. Even if the total number of courses included in the THU curriculum is larger than the number in the AAU curriculum, the THU program is designed to be completed in a shorter time compared to the AAU program. A full-time undergraduate student at THU requires a minimum of four years to complete the chemical engineering program. On the other hand, a chemical engineering student at AAU needs at least five years to complete the undergraduate program. This difference in length of program could be dedicated to the difference in the average number of courses delivered per semester, which is 6 courses for AAU and 8 courses for THU, which made it possible for THU curriculum to accommodate more courses per semester resulting in a shorter length of the program. Moreover, the AAU curriculum dedicates the entire one semester at the seventh semester of the program to an Internship for practical attachment.

3.1.2 Credit Systems

The second aspect that is taken into account in this comparative assessment is the difference in student load measurement methods (credit systems) used in the two curriculums. THU represents credits based on the conventional Credit Hours (CH) measurement. A single CH represents about one hour per week of lecture or two or more hours of laboratory work. On the other hand, student workload at AAU is represented as Credit Points (CP) which is calculated based on the European Credit Transfer Scheme (ECTS). The total CP per course is defined by using the following formula (Ethiopian Ministry of Education, 2013):

$$CP = L + T + Lab + HS \quad (1)$$

Where:

L = number of 50 - minute lecture classes per week

T = number of 50 - minute lecture classes per week

Lab = number of 50 - minute laboratory work classes per week

HS = number of home study hours dedicated set by the institution

The harmonized curriculum for the Ethiopian chemical engineering program is categorized as a module and the module is divided into three types as recommended by the organizers: core, elective and general. Some of the definitions of terms that are important for this paper are listed below (Ethiopian Ministry of Education, 2013).

Core courses: the most critical courses offered by chemical engineering department staff.

Elective courses: these courses are courses that students focus on and concentrate on a specific area of application.

General educations/courses: general education courses are general courses of engineering discipline, communication, and humanity courses that help chemical engineers to have a common view and understanding towards society and technology.

Home study: is to indicate the students' workload at home, and it specifies how much time is allotted to study for the specified load.

Classes per week: it is to indicate the number of classes a teacher teaches in one week.

Tutorial: it is assigned for the respective course to help the students by giving examples, hints, solve exercises/problems to understand the course matters better.

3.1.3 Minimum Allowed Credits Hours (CH)

Based on the credit systems discussed in the previous section, the THU requires a student total of 174 CH to complete the program, of which credits in the spring and fall are 144, and the remaining 30 CH which is for internship and practical training courses are 15 CH and credit for the final project is 15 CH held in the summer semesters (Tsinghua University, 2014). On the other hand, AAU students have required completion of 300 CP including 30 CP internship programs held in the seventh semester and 12 CP final year diploma projects on the last

semester of the program.

3.2 Course Structure Analysis

3.2.1 Curriculum Design Approach

The courses under the THU curriculum are classified into seven main categories which are further classified into subcategories based on the type of courses they contain. On the other hand, the AAU curriculum is designed based on the modular curriculum approach, which is based on the principle of dividing the curriculum into small discrete modules that are independent. The 64 courses present under the AAU curriculum are categorized into 25 modules. Table 1 and Table 2 present the general course classification of the THU curriculum and the list of modules under the AAU curriculum respectively. As shown in Table 1, the general course classification of the THU curriculum comprises the main category, subcategory, total number of courses included in the subcategory, and the credit hours (CH) for compulsory and elective courses.

Table 1. General Course Classification of THU Curriculum

No.	Main Category	Total CH	Sub Category	Courses Included	CH	CH for compulsory courses	CH for Elective courses
1.	General Fundamental Courses	26	Ideological and Political Theory	4	14	14	0
			Physical Education	4	4	4	0
			Foreign Language	4	8	8	0
2.	Cultural Quality Courses	13	Cultural Quality Education and Freshman Seminars	10	13	5	8
3.	Mathematical and Natural Science Foundation	59	Mathematics	6	21	18	3
			Physics	4	12	12	0
			Chemistry and Biology	11	26	19	7
4.	Basic Engineering Skills	13	Basic Engineering Skills	4	13	13	0
5.	Professional Courses	33	Professional Courses	24	33	28	5
6.	Practical Courses	15	Practical Courses	7	15	15	0
7.	Diploma Project	15	Diploma Project	1	15	15	0

The lists of modules under the AAU curriculum are depicted in Table 2 below. The curriculum contains 25 modules. All the module names, number of courses, and number of credit points are presented in Table 2 as follows.

Static data reveals that each country's university represents its teaching approach. Ethiopian engineering education emphasized professionalism and the development of practical skills (Mesfin, 2016). As a result, developing technical skills and working abilities is highly valued. The concept of such an idea will shorten the gap between society engineering application and school education. Consequently, undergraduates are easily able to adapt and quickly transit to engineering. On the other hand, students in China's education program have a sound theoretical base in mathematics, humanities, economics, communication skills, and professional practice; it will encourage students to develop their innovative, reasoning and communication skills since it is very important skills to be acquired by qualified chemical engineers. So, it is highly appreciated for both countries to combine professionalism and practical skills with innovation, reasoning, and communication skills to produce well-qualified chemical engineers.

Table 2. List of Modules under the AAU Curriculum

No.	Module Name	No. of Courses	No. of CPs
1	Humanity and Communication	4	20
2	Introduction to Economics	1	4
3	Applied Engineering Mathematics	4	12
4	Engineering Mechanics	2	10
5	Basic Engineering Skills	4	13
6	Advanced Mathematics and Computational Methods	2	11
7	Probability and Statistics	1	3
8	Applied Chemistry	3	16
9	Fundamental of Chemical Engineering	1	5
10	Chemical Engineering Basics	4	20
11	Fluid Machines	1	5
12	Chemical Engineering Unit Operations	5	22
13	Reaction and Biochemical Engineering	5	18
14	Strength and Engineering Materials	2	6
15	Process Industries	2	10
16	Internship	1	30
17	Basic Environmental Engineering	1	5
18	Process Control and Instrumentation	3	14
19	Chemical Engineering Process Design and Economics	3	17
20	Sustainable Energy	1	5
21	Industrial Management and Entrepreneurship	3	14
22	Research and Project	2	17
23	Elective (Process Engineering)	3	13
24	Elective (Environmental Engineering)	3	13
25	Elective (Food Engineering)	3	13

3.2.2 Ratio of Compulsory and Elective Credits

The courses in both the THU and AAU curriculums can categorize into compulsory and elective courses. From the total of 174 credits, the THU curriculum allocates 87% to compulsory and 13% to elective courses. On the other hand, the AAU curriculum assigns 96% and 4% of its credits from the minimum total credit required to compulsory courses and elective courses, respectively. By offering more elective courses at different stages of the program, the THU curriculum has proven itself to be more flexible in comparison to the AAU curriculum. By presenting all the elective courses at the final two semesters of the program, the AAU curriculum has made it possible for the students to pursue their choice of specialization by selecting among the three streams of specialization (process engineering, environmental engineering, biochemical engineering, and food engineering) at the final year of the program. Figure 1 (a, b) below presents the ratio of credits of compulsory and elective courses to the minimum allowed credits for both universities' chemical engineering programs.

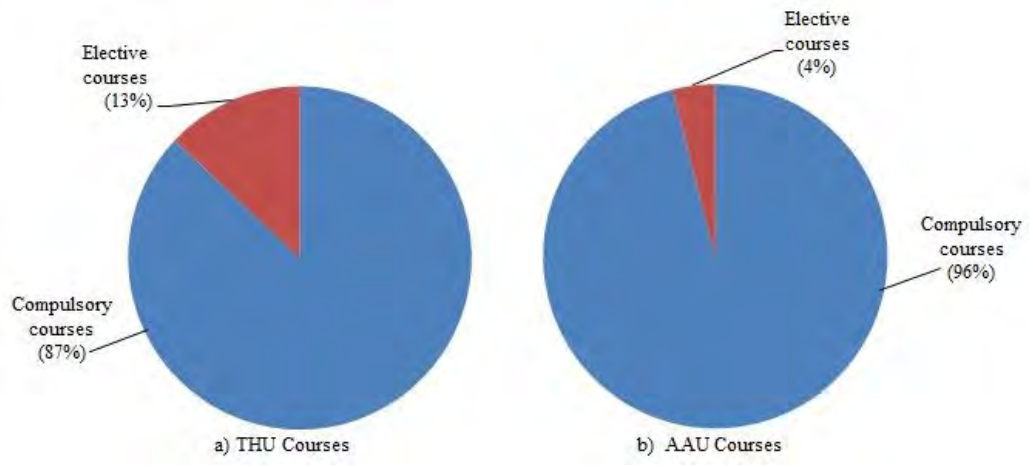

Figure 1. The Ratio of Credits of Compulsory and Elective Courses to the Total Credit for THU and AAU

3.2.3 Ratio of General, Core, and Elective Course Credits

The degree program of THU chemical engineering aims to cultivate high-level and high-quality technology and managerial talent with a solid foundation of knowledge, plus the strong practical ability and creative thinking in basic chemical engineering and related fields (Tsinghua University, 2014). Similarly, the objective of the chemical engineering program in Ethiopia is to cultivate qualified instrumental chemical engineers in the development of the country's industrial sector, perform research for needs of country development, provide consultancy and technical service, and produce global standard engineers (Ethiopian Ministry of Education, 2013). This shows that both countries have emphasized the development of chemical engineering professionals for their country's development. Courses in both curriculums can also be classified into general, core, and elective courses. General education courses credits in THU occupy 70% of the total credit. On the other hand, the ratio of general education course credits in the AAU curriculum is 26%. From this, it is evident that general education is more emphasized in THU than the AAU curriculum. In contrast, the AAU curriculum gives more focus on core courses by allocating 70% of its total credits to core courses; while the ratio of core courses in the THU curriculum is only 17% of the total credits.

Chemical engineers should be able to familiarize themselves with the basic knowledge of science and have good knowledge of updated innovations in the professional field. Students should be skillful in a wide range of general knowledge including humanity and sociology that will enable professionals a capacity to think, plan and organize their research to develop their innovation, collaboration, communication, and organizational skills. The training process in China is strong in social science and humanities. Students who have a good foundation in humanities and social science tend to be innovative, good communicators and collaborators (Gu & Lin, 2006). Conversely, in Ethiopia, the focus of the curriculum is more on core courses leaving less credit for general courses such as social science and humanity courses. If graduates want to succeed in the twenty-first century, they will need to innovate and learn new skills or enhance those they already have. Therefore, the Ethiopian chemical engineering curriculum may need to increase the credit points of social science and humanity courses to develop students' ability towards innovation, collaboration, and communication skills. Figure 2 (a, b) below shows the comparison of the ratio of general, core, and elective courses in the THU and AAU curriculum.

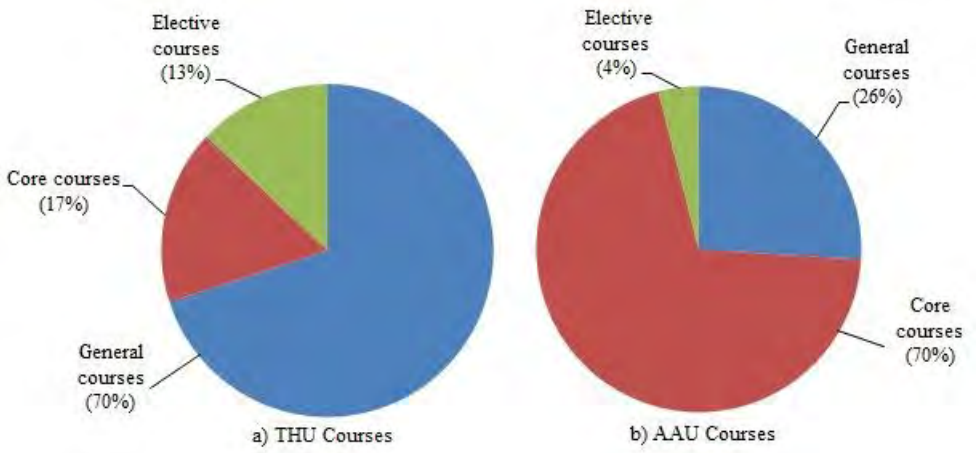

Figure 2. The Ratio of General, Core, and Elective Courses in THU and AAU Curriculum

3.3 Practical Curriculum

Practical teaching is an integral aspect of higher engineering education that will improve students' success. It primarily consists of three elements: design, experimentation, and practice. Students are taught how to apply scientific knowledge and techniques to solve practical problems by practical instruction. Practical attachment of students includes classroom, workshop instruction, and internship. When comparing practical curriculums of the two countries, THU dedicates 10% practical lessons and the AAU dedicates 24.34%. The Ethiopian program includes a one-semester internship practice in industries with 30 CP, which can inspire students to put their theoretical lessons into practice. It can allow students to practice social interaction as well as learn managerial skills and improve their working abilities. The Chinese chemical engineering program should include more internship hours for better practical attachments in industries.

The curriculum is designed to encourage multidisciplinary collaboration among students from various courses to foster the exchange of new ideas, perspectives, and skills (Loudon, 2019). Via laboratory practices, industry visits, and developing creativity, students are encouraged to investigate new concepts, materials, and technologies. Introduction to chemical engineering should have to be incorporated even in lower grades curriculum to encourage student's practical skill, innovation, research, and motivation in chemical engineering and for the industrial development of one country.

3.4 Fundamental Quality

Higher education attracts more students, which means more competition for employment. To obtain jobs, many graduates with "successful degrees" in chemical engineering are increasingly expected to demonstrate their interpersonal skills and unique qualities (Chadha, 2006). The environment of teaching and learning has also changed as a result of increased involvement. So, to make students more competent and qualified in local and global markets, the Chinese and Ethiopian chemical engineering curriculum requires an update based on the respective history, culture, and country context. Research by Tadesse et al. (2018) mentioned that the quality deficit in learning and teaching in the context of Ethiopian higher education is widening from time to time mainly due to lack of a strict quality management system and unbalanced increased enrollments and universities capacity and resources. In addition, it is also mentioned that the current approach for quality assessment of learning and teaching in Ethiopia is mainly focused on quantitative measures as an indicator for education quality. The Ethiopian chemical engineering curriculum should have to focus and look forward primarily on cultivating qualified graduates in parallel with the number of students who graduated. Ethiopia's progress nowadays towarding establishing a differentiated higher education system should be praised; it will bring quality education to the country's institutions. However, successfully implementing such a structure necessitates much more than simply classifying organizations into new categories, to bring quality education as well as sustain educational development in the country. In China, quality education has long been a priority in educational reform agenda, exam-oriented education had previously been a problem in China's education system and has been widely criticized by the public; the quality-oriented education, which is called "SuZhiJiaoYu" in Chinese, has been gradually being established (Guo et al., 2019). Profound study

and analysis of curriculum of both countries are necessarily to be further performed to improve their education qualities and make their students competitive in the global market.

4. Conclusion

After comparison of chemical engineering undergraduate programs of THU and AAU, the difference between the two curriculums can be summarized in the following aspects: (1) While the THU shortens the length of the program to 4 years in comparison to AAU of 5 years by offering more courses per semester, the AAU curriculum includes more repeated core courses with similar course syllabus, which could be merged to different single courses, this might shorten the length of the program to 4 years. (2) When comparing the credit hours and credit points, unlike the THU curriculum which measures workload by focusing on the number of class hours, the AAU curriculum takes into account both the number of class hours and the home study hours. (3) The THU curriculum offers more flexibility in its program by providing several elective courses throughout its program. On the other hand, the AAU curriculum offers an opportunity for students to pursue different specialty streams by offering elective courses in the final year of the program. (4) While general education is the important emphasis of the THU curriculum, the AAU curriculum gives more focus to core courses. In addition, the number of students who graduated in the country should go in line with the international quality standards. This will encourage the country scholars to dig, develop, and use very important indigenous knowledge and technologies to support the country's growth and introduce it to the global community.

The socio-economic and cultural backgrounds of both countries are different. Both countries should focus on the cultivation of more professional and skillful graduates by optimally including both general and core courses, and taking into account the countries' background and character. Even though the intensity of changes may differ, at each respective institutional level, it is highly appreciable by both universities to optimally add more courses to their present curriculum based on their socio-economic trait, cultural background, national demands, industrial needs, and national resource availabilities. Finally, it's recommended that both universities modify their curriculums by following up the global trend without losing focus on the socio-economic realities of their respective countries. This detailed comparison of the syllabus of the courses offered for the two countries provides a better understanding of the differences and similarities in the undergraduate chemical engineering curriculums to strengthen the merits and to focus on the drawbacks to establish a better curriculum that will fit this global competition.

Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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