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Undergraduate Mechanical Engineering Curriculum: A Cross-National Comparison of Russia and China

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Abstract

This paper presents a comprehensive cross-national comparison of undergraduate mechanical engineering curriculum in Russia and China, focusing on the case studies of Beijing Institute of Technology (BIT) and Peter the Great St. Petersburg Polytechnic University (SPbPU). This research investigates the key similarities and differences in the curriculum structure, content and learning outcomes between these two institutions. The present study adopts a mixed-methods research methodology, incorporating both qualitative and quantitative approaches. Qualitatively, the analysis focuses on examining documents and curriculum, as well as semi-structured interviews with students and professors. Whereas quantitatively, statistical methods are employed to analyze the curricular data.

academic standards, course requirements as well as curriculum content offered in both universities. The analysis results underscore the certain level of rigidity present in both programs, indicating that improvements in curriculum flexibility and the availability of elective courses could enhance the quality of the study programs. Additionally, the study suggests that reducing the current workload would be beneficial, advocating for a more balanced curriculum structure. This approach promotes a holistic educational experience rather than still focusing on numerous smaller professional courses.

Keywords: *undergraduate education, mechanical engineering education, curriculum design, comparative education, Russia, China.*

Introduction

Mechanical engineering (ME) is a critical discipline driving technological advancements globally, with a high demand for skilled professionals in the field. Our study focuses on comparing the curricular structures and teaching methods of SPbPU in Russia BIT in China to analyze their undergraduate mechanical engineering programs. The goal is to assess the breadth, depth, and alignment with modern engineering trends and demands, as well as highlight the key differences and similarities between the two esteemed educational systems.

Comparing two engineering programs in Russia and China is particularly interesting given the fact that both countries' higher education systems were built on the Soviet model of specializations.[1] China used to follow this model until the country's Opening-Up, which prompted a series of reforms influenced by domestic political, and economic developments, and Western higher education principles.[2] Similarly, Russia underwent significant changes post the fall of the Soviet Union, culminating in its adoption of the Bologna System in 2012, thereby aligning its higher education with the European Qualifications Framework.[3] By analyzing the ME curriculums of SPbPU and BIT, we explore the impact of these reforms on education systems. The selection of these institutions for comparison considers factors such as accreditation, academic reputation, and program duration to ensure a meaningful analysis. Using a mixed-methods research methodology, combining qualitative and quantitative approaches, we examine documents and curriculum content to gain insights into the undergraduate ME programs at SPbPU and BIT. Access to data from SPbPU is available through the university's official website, facilitating transparency and accessibility. Conversely, data from BIT was directly obtained from the esteemed School of Mechanical Engineering and its students, ensuring authenticity and reliability.

Overview of mechanical engineering programs at SPbPU and BIT

In Russia, Federal State Educational Standards (FSES) define the structure of education programs meticulously at the bachelor, master, and specialist levels. For engineering, these standards fall under the code 15.00.00, with ME specifically designated as 15.03.00. This specialization includes various narrower fields, each with distinct study plans and major courses. At Saint Petersburg Polytechnic University (SPbPU), the Institute of Mechanical Engineering of Materials and Transport features 5 study

Electro-physical and Electrochemical Material Processing", "Intelligent Tribology in Mechanical Engineering", "Virtual Prototyping Technologies in Mechanical Engineering" and "Equipment and Technology of Welding Production". BIT's School of Mechanical and Vehicle Engineering offer bachelor students 7 majors: Vehicle Engineering, Armored Vehicle Engineering, Energy and Power Engineering, Mechanical Engineering, Industrial Engineering, Mechanical Engineering in English, and Intelligent Manufacturing Engineering. In this study, we will focus on the Mechanical Engineering major. SPbPU example shows that Russia's ME still can be described as very narrowly specialized even within one faculty. Students are expected to focus on very particular aspects of ME, leading to them mastering a specialized skill set in a particular area. For our analysis and comparison with the Mechanical Engineering major at BIT, we have chosen the major 15.03.01 "Mechanical Engineering," specifically focusing on the specialisations under this code.

Curriculum Content

Correlation of workload and credit systems

Comparing the educational systems of the two countries presents a significant challenge owing to disparities in the definitions and interpretations of fundamental concepts pivotal to this study such as "credit", "workload" and "hour". It is imperative to elucidate these variations before proceeding with the comparative analysis. In the Russian system at SPbPU, a bachelor's degree requires a total minimum of 240 credits. The educational framework adheres closely to FSES standards that use "workload credit units" as a standardized measure to determine workload with a credit unit at SPbPU equating to 36 academic hours.[4] Conversely, at BIT, the educational landscape is characterized by a different credit system, where 1 Chinese study credit is typically equivalent to either 16 classroom hours of lectures or 32 hours of laboratory or practical work. For a four-year bachelor's degree in Mechanical Engineering at BIT, students are required to accumulate around 150 credits, including a foundation of professional basic courses, core courses, practical courses and theoretical studies.

We suggest using the ECTS credit system as a common benchmark to facilitate a more accurate comparative analysis of the two programs in this research. As 1 Russian credit is equivalent to 1 ECTS credit, SPbPU graduation requirements would stay the same and require 240 ECTS. In contrast, BIT employs the Chinese credit system, which necessitates 150 credits for program completion. However, the conversion factor between Chinese credits and ECTS credits is different; 1 Chinese credit is equivalent to 2 ECTS credits. Therefore, when converted, the total credits required by BIT amount to 300 ECTS credits. Some major differences in the distribution of study credits and workload across the academic years may be identified.

[1] Shen, W., Zhang, H., & Liu, C. (2022). Toward a Chinese model: De-Sovietization reforms of China's higher education in the 1980s and 1990s. International Journal of Chinese Education, 11(3). https://doi.org/10.1177/2212585X221124936

[2] Xiong, Weiyan & Yang, Jiale & Shen, Wenqin. (2022). Higher education reform in China: A

[3] Federal Law No. 273-FZ of December 29, 2012 On Education in the Russian Federation http://www.kremlin.ru/acts/bank/36698

[4] Regulation on the procedure for organizing and implementing educational activities for higher education programs (bachelor's, specialist, master's) https://www.spbstu.ru/upload/dmo/regulations-training-11-12-2017.pdf p. 10

Table 1: Credit requirements

	total credits, SPbPU	1 year	2 year	3 year	4 year	total credits, BIT (ECTS)	1 year	2 year	3 year	4 year
All together	240	60	60	60	60	300	100	99	58	43
General courses	33	24	9	-	-	79	18	19	1	1
Core courses	35	28	4	3	-	68	60	8	-	-
Professional courses	143	8	44	51	40	115	8	24	57	26
Laboratory work and practice	20	-	3	6	11	20	4	4	5	-
Thesis	9	-	-	-	9	16	-	-	-	16

As Table 1 shows, at SPbPU, the curriculum is structured to ensure a consistent workload of 60 credits per semester throughout all four years. For a four-year bachelor's degree in Mechanical Engineering at BIT, students are required to accumulate around 300 ECTS credits, including a foundation of professional basic courses, core courses, theoretical studies amounting to 75 credits, practical courses totalling 40 credits, and specialized graduation requirements. Also, the BIT curriculum shows a heavier concentration of credits in the first two years, with the first year comprising 100 credits and the second year 99 credits. The workload significantly decreases in the third and fourth years, with 58 credits in the third year and 43 credits in the fourth year. This structure suggests a front-loaded approach where students meet the most intense academic requirements earlier in their studies. Studying plan for the last two years is arranged in a way for students to mostly focus on more specialized courses and practical work, as well as their thesis projects. The final semesters at both universities are primarily dedicated to practical work and thesis projects. Focusing on semesters 1 through 7, we can observe that SPbPU students have a significantly higher average course load per semester, with approximately 10-11 courses, compared to BIT students, who have an average of 6-7 courses per semester. When comparing Chinese credits and undergraduate curriculums to those in the United States and Europe, Yan Guangcai notes that even the Chinese average of 6.5 courses per semester is significantly more than the US and Europe's average of 4 courses per semester. It is also stated that a higher number of courses may weaken the overall structure and coherence of the curriculum, leading to students acquiring fractured and fragmented knowledge instead of a more structured and coherent education. [1] However, when comparing the SPbPU-BIT curriculum, it is evident that the SPbPU curriculum, while being 60 credits less than BIT's, suggests more breadth within the major and offers a considerably greater quantity of professional courses and disciplines.

and Professional. By general courses, we understand foundational university courses that are designed to provide students with a broad base of essential knowledge regardless of their specific majors. Core courses are the mandatory courses students need to take before choosing their specialization and major. Under Professional courses, we united all majors and minors related to the specialization/major and listed in the study plans. As Table 2 illustrates, the SPbPU curriculum indicates a more intensive yet fragmented approach to the professional courses offered in their ME program, with a total of at least 30 major and minor professional disciplines listed in the study program. This emphasis on narrow professional courses offers students a broader knowledge base but also risks it to be segmented and not coherent and interlinked enough. In comparison, BIT's curriculum is more balanced, offering a more equal distribution between general, core and professional courses and a more consistent and coherent system.

[1] Yan, G. (2022). 研究型大学本科课程体系与结构的变革.* (The Reform of Undergraduate Curriculum and Its Structure in Research Universities). EDUCATIONAL RESEARCH General, 511(8).

Table 2: General, core and professional courses

	Culture, Life Safety, Fundamentals of Project Activities, Physical Culture and Sports	Ethics and Law, Psychology Education, Modern Chinese History, Basic Theory of Marxism, General Introduction to Mao Zedong Thought and Socialist Theory with Chinese Characteristics, Policy and Political Situation, General Education Electives
Core courses	Physics, Chemistry, Electrical Engineering, Advanced Mathematics, Engineering Graphics	Engineering Mathematics Analysis I (can be replaced by Mathematical Analysis I, II), Academic English for Specific Purposes I (can be replaced by Academic English for Specific Purposes II), Linear Algebra, Computer Science and Programming Design (can be replaced by Fundamentals of Language Programming), University Physics, Fundamentals of Design and Manufacturing I & II
Professional courses	Theory of Mechanisms and Machines, Machine Elements and Design Fundamentals, Technology of Structural Materials, Introduction to Machine Mechanics, Structure and Properties of Blanks and Parts, Strength of Materials, Theoretical Mechanics, Digital Competency Module (Digital), Engineering Graphics (Advanced Level), Environmental Issues of the Field, Introduction to Professional Activities, Fundamentals of Manufacturing Technology; Metrology, Standardization, and Certification; Computational Mathematics, Electronics, Computational Mechanics, Automation, Robotics, and FMS of Forging and Stamping Production; Forging and Stamping Equipment, Theory of Metal Forming; Theory, Technology, and Equipment of Metal Forming; Technology of Forging and Bulk Stamping; Mathematical Methods of Experimental Data Processing; Methodology of Scientific Creativity; Design of Blank Production Technologies; Project Activity; Processing of Plastics, Powder, and Composite Materials; Technology of KSO Production and Stamping Equipment; Fundamentals of Automated Design; Technological Processes and Equipment of Mechanical Assembly Production (in English); Technological Processes of Bulk Stamping (in English)	Chemistry, Fundamentals of the Life Sciences, Fundamentals of Design and Manufacturing I & II, Engineering Practice, Probability and Statistics, Physics II & III, Electrical and Electronic Technology, Theoretical Mechanics, Introduction to Mechanical Engineering, Calculation Methods, Materials Mechanics, Engineering Materials, Fundamentals of Automatic Control Theory, Fluid Mechanics and Hydraulic Transmission, Engineering Thermodynamics, Heat Transfer, Microcontroller Principles and Applications, Fundamentals of Mechanical Vibration, Mechanical Equipment Disassembly and Assembly Internship, Sensing and Measurement Technology, Mechanical Manufacturing Engineering, Design of Mechanical Manufacturing Equipment, Control and Integration of Mechatronic Systems

Here we suggest proceeding to an examination of three key disciplines prominently featured in the curriculums of both universities—Mathematics, Engineering Design, and Materials-related courses. An examination of the study materials and their coverage, including elements such as the academic schedule, credit allocation, and instructional timing, sheds light on the design and emphasis of the programs under review. This analysis allows for insights into the breadth and depth of the subject matter, as well as the balance between theoretical concepts and practical applications.

Advanced Mathematics

Mathematics is a fundamental course in both programs, spanning the entire first year of study and carrying the highest number of credits. At SPbPU, the course is valued at 14 credits, almost evenly distributed across the first three semesters (6-4-4), consisting of 90 hours of lectures and 104 hours of seminars.[1] These hours are comparable to those at BIT, where a Mathematics course consists of 192

semester and is worth 6 credits. Thus, we can note that the overall workload of the Core Mathematical Courses at BIT significantly exceeds that of the Russian counterpart.

Engineering Design

Engineering design is also one of the fundamental courses in both countries' curriculums. BIT's ME study program requires taking three Design and Manufacture Fundamentals courses throughout the entire period of study, spreading the courses through the curriculum – Course I (8 credits) is taught in the second semester, Course II (8 credits) in the third, and the most advanced one, Course III (6 credits), in the sixth semester. Initially, students learn drafting on paper through the textbooks for most of Course I. In the fifth semester, they study mechanical theory and the basics of ME along with digital production and design. Later, in the sixth semester, the focus shifts to digital design. At SPbPU, a similar approach to design courses can be found. The first Engineering Graphics course is among the core courses for STEM majors and is taught over two semesters (2 credits each) with an advanced level course in the third semester (2 more credits). Additionally, the university offers more specialized courses related to design, depending on the exact specialization and its code. For example, "Design of Blank Production Technologies" and "Design of Forging and Stamping Production Facilities" are narrow courses, each worth up to 4 credits and usually taught during the 5th or 6th semesters.

Strength of Materials

In courses related to materials and their behaviors, both SPbPU and BIT follow similar patterns in credit allocation and course distribution across semesters. In BIT's curriculum, courses like Fundamentals of Materials and Strength of Materials are offered. The Fundamentals course provides basic engineering material knowledge, while the Strength of Materials course delves into material behavior under mechanical forces, emphasizing practical and experimental learning. These courses are taught together in the fourth semester, with Fundamentals worth 4 credits and Strength of Materials worth 8 credits respectively. At SPbPU, the Strength of Materials course is among the most crucial professional disciplines, valued at 5 credits. It is spread across the 3rd and 4th semesters and focuses on mechanics models, stress analysis methods, structural elements, and practical engineering applications[2]. Along with this course, Technology of Structural Materials and Processing of Plastics, Powder, and Composite Materials courses are vital in students' study plans, offering theoretical knowledge and practical applications respectively. The Technology of Structural Materials course spread over the 3rd and 4th semesters, delves deeper into theoretical knowledge, complementing the foundational concepts covered in the Strength of Materials course. Furthermore, the Processing of Plastics, Powder, and Composite Materials course, scheduled for the final semester, focuses solely on practical applications, offering students a hands-on experience to apply their theoretical understanding of manufacturing processes.

Implications

Previous chapters of this study illustrated the existing data and provided insight into the ME curriculums of two universities, shedding light on their structures and content. A characteristic emerges when

and retain knowledge and skills. Such narrow specialization can potentially hinder their ability to apply their knowledge across broader disciplines within ME, limiting their versatility in the job market. BIT aims to prioritize a more comprehensive approach to structuring its study programs. However, the workload remains excessive, and the sheer number of courses is too high. Both of these characteristics in curriculum design ultimately led to a similar outcome. Students often become more concerned with completing assignments and passing tests rather than actually engaging with the learning process and obtaining skills and knowledge.

Another key observation was the inherent rigidity of both programs, characterized by predetermined schedules and an extensive list of mandatory courses that leave little room for student autonomy. This lack of flexibility is evident in SPbPU's curriculum, where only 10 out of the total 240 credits are allotted to elective courses, restricting students in their choices. Introducing more variability and freedom into the curriculum by allowing students to have a greater say in selecting courses or subjects to study could potentially enhance the overall quality of the programs. By encouraging a more open educational framework that empowers students to chart their academic paths, institutions can cultivate a more engaging and personalized learning experience. Another potential positive change could be the incorporation of courses taught in foreign languages, especially English. While both curriculums include courses in foreign languages for academic purposes among General Courses taught during the first two semesters, it is not relevant to any of the professional or core courses. SPbPU also provides students with "Technological Processes and Equipment for Mechanical Assembly Production" and "Technological Processes of Volume Stamping," and while these courses are valued at 7 credits each, they mostly consist of practical work and cannot be regarded as theoretical courses intended to enhance understanding of the foreign language to meet the needs of their majors.

Analyzing the programs, it is also difficult to consider these curriculums meeting the requirements of interdisciplinarity. In today's dynamic world, engineers need a diverse skill set to tackle global challenges effectively, necessitating universities to offer courses on international business, cultural intelligence, global supply chain management, and engineering leadership to prepare students.[3] At both BIT and SPbPU the responsibility for connecting with social sciences and developing soft skills is mainly assigned to just a few General Courses. At the same time, the number of credits in this area in BIT exceeds that of SPbPU by more than twice as much - 77 compared to 33, respectively. On paper and according to academic plans, the SPbPU curriculum includes an elective module for soft skills development. It consists of 24 courses, and students are given a choice of which elective they would like to take. However, only 2 credits are allocated to this module in the curriculum, and the attitude towards it is perceived as merely a "checkbox" course.

To sum up, both curriculums exhibit rigidity with limited student autonomy and lack of flexibility in course selection. Suggestions for improvements include enhancing curriculum openness, incorporating more elective courses, and integrating foreign language instruction throughout the programs. The analysis also uncovers the significant workload that students at both programs must contend with, dealing with a high credit load and many courses. The recommendation to reduce the current workload is proposed.

[1] Annotation of the course (module) "Higher Mathematics" https://www.spbstu.ru/sveden/education/documents-educational-process-educational-organization/

[2]Annotation of the course (module) " **Strength of Materials**" https://www.spbstu.ru/sveden/education/documents-educational-process-educational-organization/

[3] Toporkova, Olga. (2020). On the Content of higher technical education curricula abroad: Current Trends (Review). Vysshee Obrazovanie v Rossii = Higher Education in Russia. 29. 153-167. 10.31992/0869-3617-2020-29-3-153-167.)

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