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Engineering Education in Ukraine and Europe (18th–Early 20th Century)

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Abstract: The article examines the system of engineering education in European countries, analyzing the formation of polytechnical education in France on the example of *l'École Polytechnique* (the Polytechnic School of Paris), which became the foundation of the French educational model and influenced the subsequent development of engineering education not only in France but also in Europe. The article also highlights the process of preparing engineering professionals in Germany, one of the features of which was the introduction of vocational training. It was a type of study separate from the general system, with funding coming from local budgets or private sponsors. This strengthened the role of technical universities, which focused not only on the transmission of accumulated knowledge but also on fostering motivation for learning and scientific activities. The curricula of technical universities gradually expanded to include components of physics, mechanics, mathematics, and chemistry.

In addition, the article outlines the influence of European engineering studies on the formation of the engineering education system in Ukraine. Advances in industry created a demand for engineers with diverse specialties, which led to the establishment of an effective training system, taking into account European experience. The organizational and pedagogical contributions of Viktor Lvovich Kyrpychov to the development of domestic engineering education have been significant. However, during the massification of engineering education in the second half of the 20th century, certain issues emerged, including the fragmentation of the system and a decline in interest in professional engineering education. The more than century-old experience of training engineers in Europe and Ukraine, based on the combination of "education–science–production," can be valuable in preparing qualified professionals for today's labor market. By integrating the principles of education, scientific research, and practical application, the engineering education system can produce competent specialists capable of thriving in modern conditions.

Keywords: *archives, Europe, European technical schools, history of engineering education, history of science, primary sources, Ukraine*

Introduction

The current stage of Ukraine's development once again calls for the renewal of the content of higher technical education. Despite the certain unpopularity of engineering professions in the 21st century worldwide, it is essential to pay attention to the interconnection between engineering and the level of scientific and technological development, as well as the country's economy. The development of engineering is determined by scientific and technological progress, and the success of innovative technologies depends on the level of engineering professionals. Innovations contribute to improving the education system in line with the trends in the development of prospective industrial sectors. Engineering activities undoubtedly influence the transformation of socioeconomic and political processes. The use of innovative technologies is determined not only by the development of industry and its scientific basis but also by the quality of education. It should be emphasized that the diminished interest in engineering has a global character and is not limited to the national level of any particular country. Crisis phenomena, first associated with the spread

of the pandemic and later with Russia's aggression, have affected Ukraine's higher technical education institutions and led to the search for new approaches aimed at preparing a competitive engineering elite. In this regard, research on the initiation and development of higher technical education in European countries and conducting a comparative analysis with similar events in Ukraine becomes of great importance.

Educational processes and the history of forming the engineering education system attract the attention of both foreign and Ukrainian researchers. Various aspects of educating engineers of different profiles and an overview of the development of professional education in Western, Central, and Eastern European countries, as well as Scandinavia, have been discussed in a monograph edited by V. O. Radkevich (2018). Researchers are particularly interested in the reconstruction of the development of technical education in European countries during the 18th and 19th centuries (Yukhno, 2013; Kuzyo, 2018). The authors present a rich factual material on the establishment of the engineering education system, but little attention has been paid to educational institutions in the Dnieper region of Ukraine. Research on the peculiarities of engineering education for the mining industry (Babenko, 2016) and a thorough analysis of the development of the technical education system associated with the founding of Lviv Polytechnic (Verbitska, 2017) are also informative sources. The edited volume by Walter Rüegg (2004) is of interest as it summarizes the experience of establishing universities in Europe. More attention has been given to the French model of education in François Orivel's (2005) work. Complementing the history of Ukrainian engineering education, the issues of establishing and organizing the educational process at polytechnic centers have been enriched by genealogical research on Viktor Lvovich Kyrpychov (Radoguz, 2013), as well as jubilee practices (Sokol, 2020; Yankovskyi, 2010). The research by Onoprienko and Shcherban (1990) only fragmentarily highlights the activities of leading technical centers in Ukraine. Some information on the development of technical education in Ukraine can be derived from the biographical study by Besov and Zvonkova (2010).

The purpose of the article is to generalize on the experience of European engineering studies and explore the characteristics of national models of engineering education in Europe and Ukraine from the late 19th century to the early 20th century. The article aims to justify the methodological basis for implementing new approaches in the educational space, using accumulated experience.

The research employs an interdisciplinary theoretical and methodological approach, combining methods from historical science and related fields, along with the principles of historicism, scientificity, objectivity, comprehensiveness, and systematicity. General scientific and special historical research methods are applied, including historiographical analysis and synthesis, generalization, as well as statistical and logical methods. Historical-chronological and historical-comparative methods were used to conduct a comparative analysis of the establishment of engineering studies in Europe and the influence of key technical education principles on the formation of the system for preparing specialists in accordance with the demands of the industrial complex in Ukraine.

Engineering education in the 19th century: European studies

The professionalization of engineering in Europe began during the Renaissance, and was associated with the mechanization of artisanal production. Complex mechanisms devised during the manufacturing period influenced the formation of engineering activities and the recognition of the social status of engineers. By the end of the 16th century, the establishment of a system for training specialists in research, development, and operation of technology started, and there was a trend towards polytechnical education in universities in France, Germany, and Italy. France can be considered the founder of engineering education, as in 1671, the first higher technical institution in Europe, the Royal Academy of Architecture, was established here. In France, higher technical educational schools were founded on the basis on military schools, with the first of such schools founded in 1679. Subsequently, a series of schools specializing in engineering were established, such as the School of Engineering-Constructors of Royal Courts in 1741, the School of Bridges and Roads in 1747, the Royal Engineering School of Mézières in 1748, and the Mining School in Paris in 1783 (Yukhno, 2013; Orivel, 2005).

The opening of the Central School of Public Works by mathematician Gaspard Monge and engineer Lazare Carnot in 1794 contributed to the development of the French model of engineering education. The establishment of *l'École Polytechnique*, which aimed to train engineers and artillery officers, was associated with the events of the French Revolution, once again highlighting the connection between engineering activities and political processes. In general, the overview

educational institution of its time and influenced the formation of engineering education systems in other European countries. Higher engineering schools that were established later used the organizational experience of *l'École Polytechnique* and the educational plans of Gaspard Monge.

The Technical University in Prague, established in 1707, underwent reforms under the influence of the system of engineering education in France, particularly *l'École Polytechnique*. In 1806, the university was renamed the Polytechnic School of Prague, and offered education in German language. The renowned Ukrainian researcher and experimental physicist Ivan Puliui served as one of its rectors. The ideas of polytechnization and new approaches to educational organization were also applied in the creation of the Vienna University of Technology, known as the Imperial-Royal Polytechnic Institute, in 1815 (Müller, 1990).

The French model of engineering education also influenced the organization of technical education in Germany. The system of technical education began to take shape in Germany during the 18th century. Initially, there were centers of secondary technical education, including technical schools with a study period of 2 to 4 years, where graduates were awarded the title of engineer. Later, in the early 19th century, a network of higher technical schools emerged, such as the Technical Institute in Berlin, founded in 1821 with a two-year study period, and the Technological Institute in Karlsruhe, established as a polytechnic in 1825, and so on.

The German educational program introduced the feature of vocational training. This involved education separate from the general education system, with funding coming from local budgets or private sponsors. Depending on the specific educational program for a particular field of study, such as metallurgy or construction, a bilateral contract was signed between a student's parents and the craftsmanship system for the student's training. Later on, technical institutions of higher education were formed based on these forms of training. While the development of the first higher technical schools in Germany was initially influenced by the French model of education, the so-called Humboldtian model soon gained popularity. This style was based on two main principles. Firstly, it emphasized the financial independence of universities from the state. According to Humboldt, the state had only two tasks concerning universities: to protect their freedom and to appoint professors. Secondly, it encouraged a scientific approach to teaching. Thus, the functions of universities went beyond the mere transmission of accumulated knowledge, as was common in schools and colleges. Instead, universities demonstrated the process of scientific development, aiming

to foster motivation for learning and scientific activity. In the curricula of technical universities, the components of physics, mechanics, mathematics, and chemistry gradually increased.

Over time, Germany became a leading center for higher technical education. The creation of a corresponding system of technical training, based on the application of complex mathematical methods and achievements in theoretical physics, mathematics, mechanics, and chemistry to solve practical tasks, relied on the infrastructure of scientific institutions and laboratories (Fig. 1). Well-known scientists such as Professor F. Braun from the University of Strasbourg, worked at technical schools. Under his guidance, prominent radio physicists L. I. Mandelstam and M. D. Papalexi gained scientific experience, and later worked at the Odesa Polytechnic Institute in the 1920s and 1930s (Titze *et al.*, 1987, pp. 29–44).

Figure 1. Leibniz University Hannover. Photo by the authors, 2023.

At the University of Göttingen (Fig. 2), a powerful mechanical laboratory was established, where renowned scientists such as Felix Klein, Woldemar Voigt, and Ludwig Prandtl worked. Klein, a mathematician and author of many works in algebra, geometry, number theory, and function theory, proposed a series of original seminars aimed at integrating mathematics and engineering. During the first stage of its creation, the Technical University was headed by Carl Friedrich Gauss, followed by Bernhard Riemann. The effectiveness of the French and

German educational systems is confirmed by statistical data (Table 1). At the end of the 19th century, all universities in Germany were highly popular, and the number of students continuously increased. This growth was in line with the development of technological progress in Germany's industry (Titze *et al.*, 1987; Byrkjeflot, 2002; Ahlstrom, 1982).

Figure 2. University of Göttingen. Photo by the authors, 2022.

Table 1. Graduates of engineering universities in France and Germany from the second half of the 19th century to the early 20th century.

Country / Years	1850	1870	1880	1890	1900	1910	1914
France	6,687	12,050	15,994	21,504	28,829	38,317	42,850
Germany	3,343	11,856	24,452	32,166	41,657	59,738	65,202

Source: Authors based on Orivel, 2005; Titze *et al.*, 1987; Byrkjeflot, 2002; Ahlstrom, 1982.

Interesting facts about the implementation of new requirements in the training of doctoral candidates and their influence on the German model are worth noting. At the establishment of universities, certain academic degrees were introduced. Initially, the doctoral degree merely certified the holder's right to teach the disciplines they had mastered at the university. Later, towards the end of the 18th century, an examination involving the discussion of theses was introduced, though the scientific novelty and practical value of the topics were

practically absent. Key changes in this direction were introduced by Victor Cousin, a professor at the Sorbonne and Minister of Public Education in France. Drawing on the experience of the University of Berlin, he introduced scientific criteria in the requirements for doctoral dissertations, resulting in a noticeable improvement in their quality after 1830.

Engineering studies in England began a few years later, in the mid-19th century, influenced by the Great Exhibitions of Industry of All Nations, held in London in 1851 and Paris in 1867. These events showed that England was not competitive in the industrial market in the second half of the 19th century. One of the factors hindering industrial development was the lack of engineers. The Institution of Civil Engineers, established in 1818, did not meet all the needs. As a result, applied technical institutions were opened in the British Empire, including the Institution of Mechanical Engineers in 1847, the Royal School of Mines in London in 1851, the Royal College of Chemistry in 1853, the Royal School of Naval Architecture in 1860, and the Institution of Electrical Engineers in 1871 (Wittrock, 1993).

Under the influence of the French model, specialized technical colleges were opened to train state engineers in Spain, including Barcelona. The Federal Polytechnic in Zurich was founded in 1855 and later renamed the Federal Institute of Technology. It conducted both fundamental scientific research and applied design and engineering projects. In 1806, the engineering department of Prague University was transferred to the Polytechnic Institute, which was later divided into German and Czech institutes in 1868. These educational institutions served as the basis for the creation of appropriate technical universities in 1879.

Therefore, it can be stated that technical education in Europe had a dual direction. First, it involved the creation of separate faculties at universities, such as in Cambridge, Brussels, Belgrade, Zagreb, and others. Later, these faculties or departments became the foundation for establishing technical universities. A network of engineering studies was established in Ireland, Iceland, Romania, England, Portugal, Belgium, the Netherlands, Hungary, Greece, Switzerland, Sweden, Poland (Figs. 3 & 4), Denmark, the Czech Republic, Slovakia, Norway, Spain, Finland, and so on. These processes also had an impact on the organization of higher and technical education in Estonia. Namely, in 1632, the Tartu Gymnasium underwent a reorganization which led to the founding of the University of Tartu under the name *Academia Gustaviana*. The reopening of the university took place in 1802. Specialized technical education emerged through the activities of the Estonian Technical Society. At the initiative of

its representatives, Special Technical Courses (*Eesti Tehnika Seltsi Tehnilised Erikursused*) were opened in Tallinn, and on the basis of this institution, a technical school (*Tallinna Tehnikum*) was founded in 1919. Later, in 1923, this institution became a higher technical institution, known since 1938 as Tallinn University of Technology (Vaht, Tüür & Kulasalu, 2010, pp. 9–10).

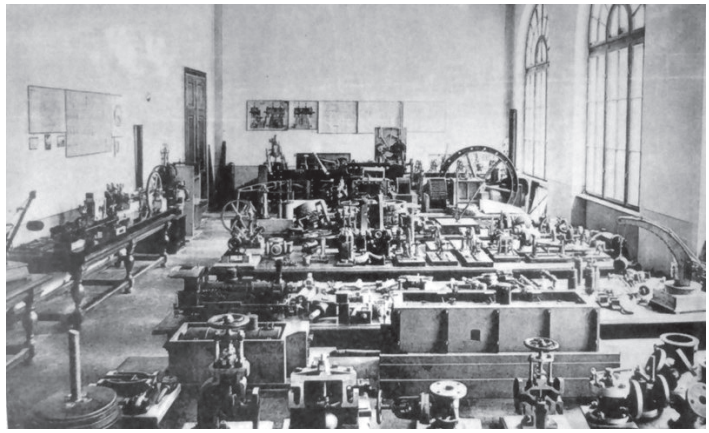

Figure 3. Chemistry laboratory (Helm, 1905). Materials of the Museum of Wroclaw University of Science and Technology.

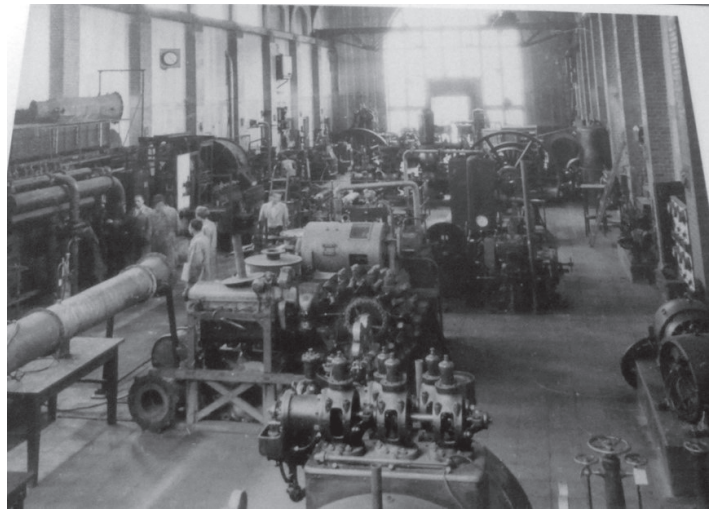

Figure 4. The mechanical-electrotechnical laboratory at *Politechnika Wrocławska*, 1948. Materials of the Museum of Wroclaw University of Science and Technology.

An overview of the establishment of engineering studies in Europe and Ukraine from the 18th to the early 20th century is presented in Table 2. The second vector focused on polytechnization, which was based on a strong foundation in physics and mathematics, modern production experience, development of technical creativity, and practical skills acquisition (Verbytska, 2017; Gutnyk & Chrzan, 2020).

Table 2. Engineering studies in Europe and Ukraine from the late 18th to the early 20th century.*

Year of founding	Institutions of higher technical education	City	Country
1745	Collegium Carolinum, Polytechnische Schule (from 1862), Herzogliche Technische Hochschule Carolo-Wilhelmina (from 1878), Technische Universität Braunschweig (from 1968)	Braun-schweig	Habsburg monarchy / Germany
1777, June 14	*Escuela* Técnica Superior de Ingenieros de *Minas* y Energía (located in Almaden, 1835 transferred to Madrid), Universidad Politécnica	Madrid	Spain
1782	Institutum Geometrico-Hydrotechnicum, Királyi József Műegyetem (from 1871), Magyar Királyi József Nádor Műszaki és Gazdaságtudományi Egyetem (from 1934), Universitas Budapest University of Technology and Economics (from 2000)	Budapest	Habsburg monarchy / Hungary
1794, February 25	l'*École centrale des travaux publics*, l'École polytechnique (from 1795)	Paris	French Republic
1796	Anderson's Institute (1796–1828), Anderson's University (1828–1877), Royal Technical College (1912), Royal College of Science and Technology (1956), University of Strathclyde (1964)	Glasgow	United Kingdom of Great Britain / Scotland

Year of founding	Institutions of higher technical education	City	Country
1806, November 10	Polytechnic Institute of the Czech Estates	Prague	Austrian Empire / Czech Republic
1811, November 26	Technische Universität Graz	Graz	Austrian Empire / Austria
1814, March 24	Scoala Superioara de Ingineri Geodezie, Universitatea Politehnica din București	Bucharest	Ottoman Empire (Wallachia) / Romania
1815, November 6	Kaiserliches Königliches Polytechnisches Institut in Wien	Wien	Austrian Empire / Austria
1816, March 7	Imperial-Royal Real School, Imperial-Royal Technical Academy in Lviv (from 1844), Lviv Polytechnic National University (from 2000)	Lviv	Austrian Empire / Ukraine
1823, December 2	London Mechanics' Institute	London	British Empire
1825, October 7	Polytechnikum, Polytechnische Schule (1865–1885), Technischen Hochschule (from 1885)	Karlsruhe	Austrian Empire / Germany
1826	Szkoła Przygotowawcza do Instytutu Politechnicznego (1826–1831), Warszawski Instytut Politechniczny im. Cesarza Mikołaja II (1898), Politechnika Warszawska (from 1915)	Warsaw	Kingdom of Poland (Russian Empire) / Poland
1827	Teknologiska institutet, Kungliga Tekniska Högskolan (from 1877)	Stockholm	Swedish Empire
1828, May 1	*Technische Bildungsanstalt*, *Königlich Sächsische Technische Hochschule* (from 1890), Technische Universität Dresden (from 1961)	Dresden	Austrian Empire / Germany
1828, November 28	St. Petersburg Institute of Technology	St. Peters-burg	Russian Empire / Russia

Year of founding	Institutions of higher technical education	City	Country
1829	Königliche vereinigte Real- und Gewerbeschul, Polytechnikum (from 1876), Technische Hochschule Stuttgart (from 1890)	Stuttgart	Austrian Empire Germany
1829, November 5	Chalmers Tekniska Högskola	Gothenburg	Swedish Empire
1829, November 5	Den Polytekniske Læreanstalt, Danmarks tekniske Højskole (from 1933), Danmarks Tekniske Universitet (from 1994)	Kongens Lyngby	Danish Empire / Denmark
1830	Moscow Craft Educational Institution, Imperial Moscow Technical School (from 1868), Moscow Higher Technical School (from 1918)	Moscow	Russian Empire / Russia
1831, May 2	Höhere Gewerbeschule, Königliche Technische Hochschule Hannover (from 1879), Universität Hannover (from 1978), Gottfried Wilhelm Leibniz Universität Hannover (from 2006)	Hannover	Austrian Empire / Germany
1833, November 11	Königliche Polytechnische Schule (till 1864), Königliche Industrieschule (1870–1907)	Augsburg	Austrian Empire / Germany
1836	University of London	London	England
1837	Εθνικό Μετσόβιο Πολυτεχνείο	Athens	Greece
1837	École des mines du Hainaut, l'École des arts industriels et des mines (from 1872), l'Université de Mons (UMons) (from 2009)	Mons	United Kingdom of Netherlands / Belgium
1842, January 8	Koninklijke Academie, Polytechnische School (from 1864), Instituut voor Technologie (from 1905), Technische Universiteit Delft (from 1986)	Delft	Netherlands

Year of founding	Institutions of higher technical education	City	Country
1849, January 15	Helsingin teknillinen reaalikoulu, Polyteknillinen koulu (from 1872), Polyteknillinen Opisto (from 1879), Suomen Teknillinen Korkeakoulu (from 1908), Teknillinen korkeakoulu (from 1942), Aalto-yliopiston teknillinen korkeakoulu (from 2010)	Helsinki	Russian Empire / Finland
1849	Technicke učiliště, C. k. česka technicka vysoka škola Františka Josefa v Brne (from 1899), Vysoke učení technicke v Brne (from 1961)	Brno	Austrian Empire / Czech Republic
1852, December 30	Instituto Industrial de Lisboa, Instituto Industrial e Comercial de Lisboa (from 1869), Instituto Superior Técnico (from 1911), Instituto Superior de Engenharia de Lisboa (from 1974)	Lisbon	Portuguese Empire / Portugal
1853, November 7	l'École spéciale de Lausanne, Faculté technique de l'Académie de Lausanne (from 1869), l'Ecole d'ingénieurs de l'Université de Lausanne (from 1890), l'École polytechnique de l'Université de Lausanne (from 1944), École polytechnique fédérale de Lausanne (from 1963)	Lausanne	Switzerland
1855, October 16	Eidgenössische Technische Hochschule	Zürich	Switzerland
1859, November 13	La Regia Scuola di Applicazione per gli Ingegneri di Torino, Politecnico di Torino, Regio Politecnico di Torino (from 1906)	Turin	Italy
1859, November 15	Istituto Tecnico Superiore, Politecnico di Milano	Milan	Italy
1862, October 14	Rīgas Politehniskā institūta, Rīgas Tehniskā universitāte (from 1990)	Riga	Russian Empire / Latvia

Year of founding	Institutions of higher technical education	City	Country
1868, April 12	Polytechnische Schule München	Munich	Austro-Hungarian Empire / Germany
1870, October 10	Königlich Rheinisch-Westphälische Polytechnische Schule zu Aachen	Aachen	Austro-Hungarian Empire / Germany
1873	l'École des sciences appliquées aux arts et à l'industrie, École Polytechnique de Montréal (from 1894)	Montreal	Canada
1877, October 10	Technische Hochschule, Technische Universität Darmstadt (1997)	Darmstadt	Austro-Hungarian Empire / Germany
1879, April 1	Die Königlich Technische Hochschule zu Berlin	Berlin	Austro-Hungarian Empire / Germany
1887	College of Technology, Dublin Institute of Technology (from 2019)	Dublin	United Kingdom of Great Britain and Ireland / Republic of Ireland
1885, April 16	Kharkiv Practical Technological Institute, NTU "Kharkiv Polytechnic Institute"	Kharkiv	Russian Empire / Ukraine
1898, August 31	Kyiv Polytechnic Institute of Emperor Oleksandr II, NTUU "Igor Sikorskyi Kyiv Polytechnic Institute" (from 2016)	Kyiv	Russian Empire / Ukraine
1899, September 30	Katerynoslav Higher Mining School, NTU "Dnipro University of Technology" (from 2018)	Dnipro	Russian Empire / Ukraine
1902, October 2	Peter the Great St. Petersburg Polytechnic University	St. Peters-burg	Russian Empire / Russia

of the educational landscape in France at that time confirms the extraordinary fragmentation and specialization of education, resulting from the various events during the revolution. Napoleon's Consulate introduced a system of bureaucratic administration that left no place for the autonomy of the classical university, and universities were replaced by professional schools.

The first curriculum for *l'École Polytechnique* was developed by its founder, Gaspard Monge. Focusing on fundamental disciplines such as mathematics and chemistry, along with additional courses in descriptive geometry, the program spanned three years of study. Practical training for future engineers was of great importance, although the theoretical preparation was conducted at a very high level. The teaching was conducted by renowned scientists and professors, such as Gaspard Monge for descriptive geometry, Joseph-Louis Lagrange for theoretical mechanics, André Ampère for electrodynamics, Sadi Carnot (son of Lazare Carnot) for the fundamentals of thermodynamics, Pierre Laplace for mathematical physics, next to Louis Gay-Lussac, Gaspard de Prony, and others (Rüegg, 2004, pp. 3–10).

At *l'École Polytechnique*, Gaspard Monge proposed interesting pedagogical approaches, aimed at implementing active teaching methods and fostering leadership qualities among students. He selected an obvious leader within the group and allowed him to conduct sessions for his peers alongside the teacher. Despite the strong military component of the *Polytechnique*, the faculty independently determined the content and teaching methods for disciplines. Gradually, mathematical analysis and mechanics became the priorities, which influenced the content of the curriculum. New vectors of teaching were defined by the French mathematician and mechanic Pierre-Simon Laplace. The duration of the program was reduced to two years, focusing more on theoretical aspects, while practical components were postponed to the next level of education. Students were selected based on competitive grounds and were at least 17 years old. They also had to agree to serve in the public service for at least ten years after completing their studies. In other words, state education was seen as a branch of public administration. Academic degrees and selection methods through competitions and exams were organized in a specific hierarchy. Later, the educational programs of *l'École Polytechnique* were reoriented towards the first level of engineering education—a bachelor's degree with a solid foundation in theoretical physics and mathematics (Weisz, 1983, pp. 33–46).

France became the first country to initiate fundamental training for engineers based on the mechanical approach. *L'École Polytechnique* was the most modern

Year of founding	Institutions of higher technical education	City	Country
1904, October 1	Königliche Technische Hochschule zu Danzig, Reichshochschule Danzig (from 1941), Politechnika Gdanska (from 1945)	Gdansk	Austro-Hungarian Empire / Poland
1910, September 15	Norges Tekniske Høgskole	Trondheim	Norway
1910, October 1	Technische Hochschule Breslau, Politechnika Wrocławska (from 1945)	Wroclaw	Austro-Hungarian Empire / Poland
1918, September 18	Odesa Polytechnic Institute, Odesa Polytechnic National University (from 2021)	Odesa	Russian Empire / Ukraine
1919, October	Eesti Tehnika Selts, Tallinna Tehnikakool (from 1920), Tallinna Tehnikainstituut (from 1936), Tallinna Polütehniline Instituut (from 1944), Tallinna Tehnikaülikool (from 1989)	Tallinn	Republic of Estonia
1919	Państwowa Wyższa Szkoła Budowy Maszyn, Państwowa Wyższa Szkoła Budowy Maszyn i Elektrotechniki (from 1929), Państwowa Szkoła Inżynierska (from 1945) Politechnika Poznańska (from 1955)	Poznan	Poland

* The table presents generalized information about the development of the network of higher polytechnic schools in Europe and Ukraine. European polytechnic studies emerged on the basis of the first engineering or technical centers as early as the late 18th century, but the professional classical training of engineers was started later. These facts somewhat influence the approach to defining the inception of polytechnic institutions. Prior to that, some institutions were formed as a result of the dissolution of previous centers. Having incorporated authentic (original) information from the history of European studies, the authors have refined and expanded the network of higher polytechnic schools in Europe.

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Training of engineers in Ukraine

The establishment of higher technical education in Ukraine was driven by the needs of the developed industrial region known as the Industrial South of the Russian Empire. The reforms of the 1860s–1870s contributed to the development of metallurgy, mining, and mechanical engineering industries. Large industrial enterprises emerged, employing the modern technology of the time. Mechanical plants operated in Kyiv, Kharkiv, Mykolaiv, Odesa, Sumy, Mariupol, Bila Tserkva, and Katerynoslav (now Dnipro), with widespread implementation of electric power drives. In 1896, the Luhansk Cartridge Works was electrified, and from 1896 to 1898, the Kharkiv Steam Locomotive Plant installed seventy-seven electric motors to drive machines (drilling, turning, milling, etc.) and eight electric overhead cranes.

As industrialization progressed and large industrial enterprises were established, the energy sector also started to develop. Although educational institutions like the Kyiv Mining School (founded in 1834) and the Scientific-Practical Institute of Railway Transport (established in 1856) existed in the Ukrainian territories, they were unable to meet the demand for engineers of diverse qualifications in the industry (Gutnyk, Tverytnykova & Sklyar, 2019).

The absence of higher, middle, and lower technical educational institutions had a significant impact on the economic state of industry in the Industrial South. One of the main organizers of the engineering education program in Russian Empire at the end of the 19th century was Viktor Lvovich Kyrpychov, who was a member of the Russian Technical Society and the founder and head of the South Russian Society of Technologists. Together with Professors I. O. Vyshnegradskyi and D. I. Mendeleev, they worked on developing vocational education, involving representatives from all levels of industrial production: engineers, technicians, masters, and workers (SAKhR, F. 770, Desc. 1, case 469, pp. 3–6).

The first stage of technical education was available at the Real School of Lviv, established in 1816, when this territory of Ukraine was under the rule of the Austrian Empire. Later, the school was reorganized into the Imperial-Royal Technical Academy, which became the basis for the creation of Lviv Technical Academy in 1844. The latter adhered to the principles of polytechnic education. Three specialized technical schools operated under the academy, focusing on engineering, construction, and chemical technology. The structure was built upon faculty principles. In 1877, the academy was renamed the Technische Hochschule and acquired the status of a high-quality technical educational

institution. However, this did not address the overall issue of the shortage of specialists for the industry (Gutnyk, Tverytnykova & Chrzan, 2021).

To improve the training of engineering personnel for the industrial complex, the Practical Technological Institute (PTI) was established in Kharkiv in 1885. It became a center for the development of technical sciences and laid the foundation for the emergence of scientific collectives (Figs. 5 & 6).

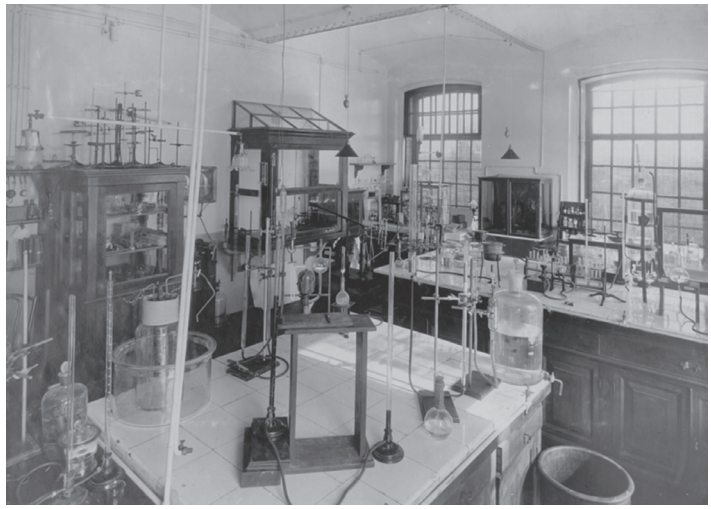

Figure 5. Professor O. P. Lidov's cabinet of chemical technologies at KhPTI, 1885. Collection of the Historical Museum of NTU "KhPI."

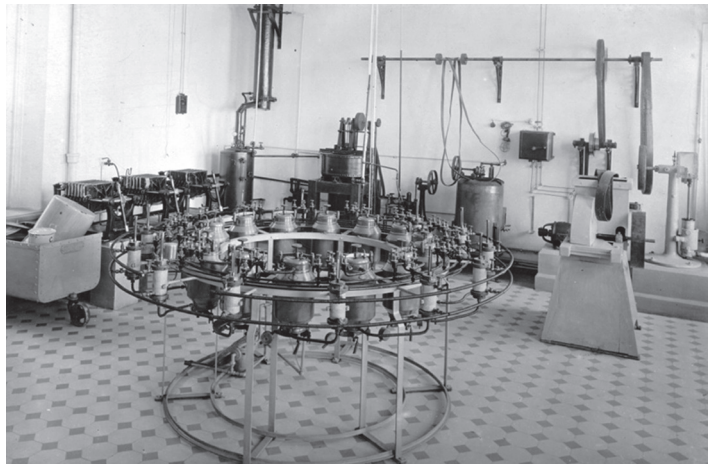

Figure 6. The laboratory of sugar production at KhPTI, 1885. Collection of the Historical Museum of NTU "KhPI."

During the organization of KhPTI, Kyrpychov formulated his views on the system of higher technical education. He considered the combination of lectures with seminars, laboratory work and practical classes, and compulsory industrial practice as the main method of teaching. Kyrpychov emphasized the importance of studying applied sciences, based on general theoretical disciplines, which would foster the "ability to do something new." He also believed that a well-educated engineer required a strong fundamental theoretical background. Thus, when proposing the organization of higher technical education, Kyrpychov suggested drawing upon the experience as well as material and technical base of universities. For the preparation of scientific staff and instructors, it was obligatory to conduct internships abroad in higher technical schools across Europe. Sending professors and students to industrial enterprises facilitated conducting applied research and maintaining connections with scientific societies. Professors actively participated in congresses and scientific conferences. Scientific societies began to develop, which at that time became one of the influential forms of organizing scientific activity (SAKhR, F. 770, desc. 1, Case 29, p. 2).

In the academic year 1896–1897, the student body at Kharkiv Practical Technological Institute (KhPTI) consisted of 699 individuals. Of the 375 applicants who took the competitive entrance exams, only 167 were admitted. Meanwhile, over 400 students from the Russian Empire were studying in foreign higher technical schools. As Kyrpychov mentioned in his speech at the Trade and Industrial Congress of the Department of Industrial Education in 1896 in Nizhnyi Novgorod, the demand for engineers and technologists continued to grow. He stated, "as the director of a higher educational institution and the chairman of the South Russian Society of Technologists, I am in despair: I have requested 10 technologists, but I can only recommend two…" (Kyrpychev, 1895, pp. 48–50).

In 1897, the Russian Technical Society established the Commission for Higher Technical Education Institutions, which included many outstanding scientists such as D. I. Mendeleev, D. S. Zernov, M. P. Konovalov, and others. The commission recognized the need for expanding higher technical education. Consequently, in 1898, Kyiv Polytechnic Institute was founded, comprising four departments: mechanics, chemistry, agronomy, and engineering (Fig. 7).

The organizational and administrative work was entrusted to the experienced Professor Kyrpychov, who devoted his accumulated experience and pedagogical talent to the implementation of polytechnic training for engineers. In addition to profound theoretical preparation, Kyrpychov's lectures were always

Figure 7. Kyiv Polytechnic Institute (cafeteria and educational auditory), 1902. Materials from the State Polytechnic Museum named after Boris Paton, Igor Sikorsky Kyiv Polytechnic Institute.

accompanied by experiments, which he regarded as a means of direct research and verification of theoretical results. Significant emphasis was placed on practical aspects. The institute established a network of state-of-the-art laboratories for that time. Kyrpychov emphasized the importance of a creative approach to education, which fostered students' ability to experiment. In his lecture 'The Significance of Imagination for Engineers,' the professor expressed the idea that successful technological development required not only diligent work but also the presence and cultivation of creative imagination (State Archives in the City of Kyiv, F. 18, Desc. 1, case 71, pp. 2–7; case 8, pp. 8–9).

The growth of the mining industry introduced the need for engineers with expertise in mining. In the territory of the Katerynoslav Governorate, the first mining schools were established, including those at the Luhansk Foundry Plant (1823) and the Lysychansk Mining School (1836). In 1899, Katerynoslav Higher Mining School was established (which later became the National Technical University "Dnipro Polytechnic"), with a focus to prepare engineers for the mining industry. This was reflected in the curriculum, which included subjects such as higher mathematics, analytical mechanics, building mechanics, applied mechanics, mining plant mechanics, physics, chemistry, electromechanics, mineralogy, geology, mining art, metallurgy, and others. In 1912, the institution was renamed Katerynoslav Mining Institute. Responding to the industry's needs, new departments were opened, and a mechanical faculty with specializations in mining plant mechanics and electromechanics was established (Babenko, 2016).

The Odesa Polytechnic Institute, founded on September 19, 1918, adhered to the principles of polytechnic education. The institute's structure included three faculties with departments that addressed the specific needs of the region: the Mechanical Faculty with electromechanical, shipbuilding, and mechanical departments; the Engineering and Construction Faculty with engineering-hydrotechnical and sanitary-technical departments; and the Economic Faculty with administrative-financial and trade-industrial departments (Honcharuk, 2018).

It is worth noting that the establishment of polytechnic institutions in Ukrainian territories contributed to the formation of a model of physical-technical education that was based on the synthesis of profound theoretical preparation and practical components. These institutions also developed a network of scientific research laboratories to provide students with scientific and practical skills, in line with European trends in engineering studies (Tverytnykova, Demidova & Salata, 2023).

Conclusion

The need for technical specialists in France led to the establishment of a network of engineering schools. The most famous among them, *l'École Polytechnique*, became the foundation of the French education model and had a significant influence on the further development of engineering education not only in France but also in Europe. The educational plans of *l'École Polytechnique* served as the basis for organizing education also in higher technical schools in Prague and Vienna. The pedagogical approaches used in teaching at that time remain relevant today. The creation of engineering centers in France also played a significant role in the development of the German engineering education system. The intensive growth of Germany's industry contributed to the establishment of technical education, while the deepening of the education system, in turn, accelerated scientific and technological progress. Gradually, the German engineering education system took the leading position and influenced the development of specialized engineering education in Europe and Ukraine.

At the beginning of the 20th century, there were four polytechnic institutions in Ukraine, all focused on the polytechnicization of technical education. The industry's demand for specialized engineers led to the establishment of an effective training system, drawing on European experience. A remarkable contribution to the creation of the domestic engineering education model was made by Viktor Lvovich Kyrpychov, the director of two leading technical universities in Ukraine. However, the massification of engineering education during the second half of the 20th century introduced certain adjustments, primarily the fragmentation of the system and a decline in interest in professional engineering education. Nonetheless, in the context of modernization of higher technical education in Ukraine, the search for new approaches aimed at improving the technical education system and increasing its quality plays a crucial role. The more than a century-old experience of engineering education in Europe and Ukraine, based on the combination of "education–science–production," can be beneficial in preparing qualified professionals who can succeed in the contemporary job market.

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