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American Engineering Education In International Context: Alois Riedler and the Reform of German Engineering, 1893-1914

Abstract

In 1893 Prof. Alois Riedler of the Royal Technical University of Berlin was commissioned by the Prussian Ministry of Education and Culture to investigate American engineering education. At the same time he also served as a technical correspondent for the Association of German Engineers and wrote extensively on American technology on display at the World's Columbian Exposition for the Association's journal. Riedler's interest in American engineering education had its origins in his role as a jury member at the Philadelphia Centennial in 1876 and his admiration for the accomplishments of American civil and mechanical engineers, whom he considered to be among the world's best. He was also the leading German proponent of reform of engineering education away from overly abstract and theoretical instruction, equal standing for newer technical universities with traditional institutions of higher learning, and improvement in the professional and social standing of the engineer in German society.

Riedler's report singled out programs at Cornell University, Massachusetts Institute of Technology and Stevens Institute of Technology as engineering curricula worth emulating by German technical universities. He believed that the hours spent in practical laboratories, as the best American programs required, offered hands-on and practical experience for engineers in training. Materials testing facilities offered both faculty and students the opportunity to perform real research of value to the engineering profession and society at large.

Riedler's conclusions won quick approval in professional engineering circles in Germany. The Association of German Engineers took up his recommendations and incorporated them into a series of resolutions to be forwarded to state governments to increase the funding for technical universities, to change the curriculum promoting laboratory practice and create practical testing facilities. The reforms, inspired by American engineering school education, profoundly changed the nature of German engineering in the 20th century.

Introduction

Prof. Alois Riedler of Berlin's Royal Technical University spent most of the year 1893 in the U.S., reporting on the World's Columbian Exposition in Chicago for the journal of the Association of German Engineers and gathering material for a study of American engineering education commissioned by the Prussian Ministry of Education. After returning from a grand tour of the American West, he exclaimed, "America owes its greatness, achieved in such an unparalleled short time span, to the civilizing influence of the engineer. The engineer is not only the pioneer of civilization in the wilderness… but nowhere else in the world is the work of the engineer of greater importance."[1] So powerful was the force of rapid American development in the world that Germany had no choice but to study it carefully and see what lessons it might yield for the Old World, Riedler insisted. Riedler was no stranger to the New World, having visited the Philadelphia Centennial of 1876 and written accounts of American technology on display for the Austro-Hungarian government's official report.[2] But in 1893 Riedler's praise was not reserved for accomplishments of individual inventors like Thomas Edison or George Corliss. He focused his attention instead on the achievements of a corps of professional engineers, and on the qualities of an educational system that had fostered such excellence.

American engineering education had begun to enjoy world-wide renown by 1893. Prof. John Goodman, newly appointed to a chair at England's Yorkshire College of Science quoted a senior colleague who advised him, "Now the very first opportunity you get, go over and see what the Americans are doing, and you will see there technical education carried out with the greatest efficiency."[3] What most impressed foreign observers were the pedagogical possibilities of laboratory-based instruction in the engineering education curriculum. Laboratories gave students hands-on experience and exposed them to the tools and production techniques they would encounter in the workshops, factories and engineering offices where they would eventually find employment. Laboratories made it possible for professors and students alike to engage in real research on practical problems, such as testing the strength of metals and alloys. Laboratories offered the opportunity to conduct research as a fee-based service for private industry and thereby defray their cost. Laboratories furthermore provided employment for postgraduate students and forged links with industry that could yield employment opportunities for students or philanthropic gifts to universities. The advantages of laboratory-based instruction may seem obvious to anyone teaching science or technical courses today. In the late 19th century, however, engineering educators in the U.S. and elsewhere were compelled to justify to university administrators the additional equipment cost, upkeep and personnel necessary for the laboratories themselves and justify the greater good in the relatively inefficient student-teacher ratios such instruction necessitated.[4]

Robert H. Thurston and Laboratory Instruction

The father of instructional laboratories for engineering students was Robert H. Thurston, the first chair of mechanical engineering at Stevens Institute of Technology in Hoboken, New Jersey. Thurston was an instructor at the U.S. Naval Academy in Annapolis when the first president of Stevens, Henry Morton persuaded him to take up a post at the new university in 1871 and gave him virtual *carte blanche* at designing the curriculum for mechanical engineers. Thurston had traveled widely in Europe and had visited technical colleges looking for practices which might work well in the context of American education.[5] The training of engineers, especially civil engineers, at universities like Rensselaer Polytechnic Institute or the United States Military Academy at West Point, had been heavily influenced by French and German examples in the years before the Civil War. As Monte Calvert pointed out, from France came the emphasis on math and science and the concept of a high level professional school; from Germany came the practice of setting up schools to train technical personnel at all levels with a research institution at the top.[6]

Continental examples could inspire and inform Thurston's curriculum but copying from them was out of the question. Both France and Germany had adopted relatively uniform systems of secondary education by the 1870s, systems certified by the state to insure a *Gymnasium* graduate, for instance, had learned Greek, Latin, and a modern language, had undertaken at least a year of chemistry and physics and had studied mathematics to the level of calculus.[7] Though American common or elementary schools had begun to achieve uniform educational standards befitting late 19th century expectations with an emphasis on literacy, numeracy and civics instruction, the status of secondary or grammar schools was still fluid, and only a minority of an age cohort attended much less graduated from high school.[8] Prof. George F. Swain of the Massachusetts Institution of Technology estimated that the student entering his institution was approximately 2 years behind his German counterpart.[3] The very diversity of American secondary education, split between rural and urban school districts, public and private schools, academy, grammar, or high school, with standards differing from state to state, created a host of problems for Thurston. The solution Stevens and other engineering schools adopted was to set a list of prerequisites in science and math for admission and further to test candidates to determine their skill levels. Stevens, Cornell and other universities were then obliged to set up special high schools to provide instruction to students who failed to pass the entrance exam or whose secondary school training failed to meet the list of prerequisites.[5]

Thurston devised a four-year curriculum for mechanical engineers that emphasized physical materials in the first year, including concepts like strength, measure of elasticity, friction and lubrication; the second year was devoted to tools, and tool-making, machinery, millwork, power, loads and power transmission; in the third year students focused on prime movers, from waterwheels to steam engines, compressed air and gas and electrical motors. In the fourth year students applied this learning to railroads, ships, factories and foundries and took a course in general business as it applied to a practicing engineer. Physics, chemistry and higher mathematics were integral to the curriculum in the sense that they were taught in conjunction with an engineering application and as natural sciences in themselves.[10] He envisioned laboratories to aid in testing materials strength and elasticity, determining coefficients of friction and lubrication testing, tool testing, power transmission and engines of all sorts. In 1874 the trustees of Stevens Institute approved his request to set up a mechanical laboratory and purchase tools, equipment, testing devices and engines.[4]

The Philadelphia Centennial

Thurston's opportunity to show his laboratory and popularize his educational ideas among engineering educators came in 1876 at the Philadelphia Centennial. Alexander

Lyman Holley, one of the nation's most distinguished engineers, pioneer of the Bessemer process in the U.S. and active as a partner in Andrew Carnegie's Edgar Thomson Steel Works, used his presidential address at the American Institute of Mining Engineers in February, 1876 to call for more practical instruction of engineering students as apprentices or interns in private industry.[12] Holley's suggestions were taken up by a combined meeting of the associations of both the IAME and American Society of Civil Engineers in June, 1876 and on the program of the International Conference on Education in Philadelphia later. Holley and Thurston were good friends who corresponded on the subject of engineering education and later helped found the American Society of Mechanical Engineers.[4]

Thurston publicized his ideas on the use of laboratories in engineering education in articles in Scientific American in 1874 and 1876, in an article in The Journal of the Franklin Institute in 1875 and in a display of testing equipment from Stevens on the grounds of the Centennial. The Federal government lent its prestige to Thurston's mechanical laboratory in 1875 when it awarded Stevens a grant to test the physical properties and strength of alloys of copper, zinc and tin.[4] Thurston's timing in the mid-1870s for promoting his ideas on engineering education was ideal.

Congress had passed the Morrill Land Grant Act in 1862 allotting the proceeds from the sale of public lands in the West for individual states to create colleges promoting agriculture and the mechanical arts. Only well after the end of the Civil War did most states begin to see the proceeds of the sales and establish colleges befitting the terms of the act.[10] The University of Wisconsin, for instance graduated its first agriculture student in 1880 and its first engineer several years later, while Ohio State's entire enrollment in agriculture in 1878 was 7 students.[11] Engineering departments in particular sought models for effective instruction and means of attracting enrollment. Thurston's ideal of laboratory-based engineering instruction was widely copied in the new land grant state universities, especially those in the Middle West.

Early Reports on American Engineering Education

The Centennial provided the occasion for German observers to take note of Thurston's methods, too. Hermann Grothe's American Industry (1877) was the work of a civil engineer who became an expert in textile machinery, patents and technical journalism.[12] Most of the book lauds the development of American industry from the perspective of a German industry spokesman who wanted to copy America's protective tariff legislation. But Grothe also noted Thurston's work in metallurgy at Stevens and the general progress of scientific and engineering education at the land grant institutions and the Columbia University School of Mines. More closely focused on the question of laboratory-based instruction was a lecture in 1877, later an article, for the Association for the Promotion of Economic Efficiency, entitled "Notes on Technical Education in North America, by Hermann Wedding, a professor who taught at the School of Mines in Berlin and later at the Royal Technical University. Wedding was often a judge and reporter at late 19^{th} century world's fairs especially in the fields of mining and the iron and steel industry.[9]

Wedding reviewed the short history of American technical education but reserved the majority of his piece to extended studies of Stevens Institute and the Columbia School of Mines. He declared that the New York school was probably the best outfitted mining school in the world, though it was clearly the Hoboken Institute that captured his imagination. He devoted half of his article to Stevens' curriculum, its facilities and professors, and the innovation of the mechanical testing laboratory. Wedding especially liked the fact that students had the "the opportunity to participate in the experiments on steam engines, boilers, and other operations that occur in practical life." Nowhere in Germany was there such emphasis on laboratories, significant because they were "the connecting link between science and industrial practice that had been missing until then."[9]

Anyone interested in the history of science and technology might find it ironic that a German professor was complaining about the absence of laboratories when Germany considered itself the birthplace of the university laboratory. Furthermore, German technical universities, especially the earliest one in Karlsruhe, were models for MIT, Cornell and Stevens.[26] The chemical laboratory of Justus von Liebig at the University of Giessen dates to the 1820's and 1830s[13]; indeed one of Liebig's American students, Eben N. Horsford, is usually credited with introducing laboratories to American universities when he became professor of chemistry at Harvard University in 1847[14]. But the technical universities in Germany faced a struggle for standing in the academic world with traditional universities just as the land grant institutions strove for equality with traditional universities in this country. In their quest for legitimacy the technical universities accepted only those students with the traditional *Gymnasium* education in the sciences and languages and the certificates to prove it. Furthermore, professors at technical universities sought to turn engineering into pure applied science. Practical application, they believed, was reserved for vocational schooling, not universities. The consequence was that German technical universities were graduating mechanical engineers with high-level skills in mathematics, physics and chemistry but no work experience and no knowledge of the day-to-day routine of the mills and factories where they would be employed.[15] The man who deserves credit for changing this state of affairs was Alois Riedler.

The Reforms of Alois Riedler

Riedler was born near Graz, Austria into a middle class family. His first look at American technology came when he was just 17 years old and visited the Paris World's Fair of 1867 when Elias Howe, Samuel F. B. Morse and Cyrus Field were honored for their contributions, and the Corliss Steam Engine, the locomotive "The General", and the machine tools of William Sellers showed the world the range of America's inventive genius. Riedler received his technical education at technical universities in Graz and Brunn, and later in Vienna where he became a protégé of Austria's most important professor of mechanical engineering, Johann von Radinger.[16] Something of prodigy, Riedler published his first technical essays at 21 while still a student at Graz and, still in his twenties, was entrusted with writing reports for the official commission of the Austro-Hungarian government on the Philadelphia Centennial and the Paris World's Fair of 1878.[17]

He received his first appointment as adjunct professor at the Technical University Munich in 1880, moved to the Technical University at Aachen in his first regular appointment in 1884, and finally was called to a chair in Berlin in 1888.[18] He specialized in improving the capacity, speed and efficiency of pumps in urban water and sewer systems, in factories and in mines. He invented and patented pumps for large systems, and even served as consulting engineer on new pumps in places as diverse as Paris and Newark, New Jersey. Whether the subject was pumps, steam engines, machine tools or gas motors, he believed that the faster the mechanism operated, the more efficient and economical it could be run.[19]

From his post in Berlin Riedler worked tirelessly on reforming the education of German engineers and raising their status to the ranks of valued and well paid professionals like doctors or lawyers. As Kees Gispen's study of German engineers demonstrates, technical universities turned out more graduates than industry could profitable employ, and engineering graduates faced job competition from graduates of technical institutes at the secondary school level. Technicians from institutes were cheaper to employ and often performed as well on the job as their university-educated counterparts because the institutes stressed practical, hands-on experience.[15] Riedler also sought to raise their status level by conferring the doctorate degree on engineers, a right reserved until the end of the 19th century to the traditional universities.

An additional advantage of his professorship in Berlin were the contacts he made with leading scientists, inventors and government officials including Werner von Siemens, Emil Rathenau, Ludwig Loewe, even Kaiser Wilhelm II. For his reputation as the most distinguished engineering professor in Germany, his sometimes haughty demeanor and his connections in the highest ranks in the capitol, he was known as the *Grand Seigneur*.[18]

Germany and Chicago's World's Columbian Exposition

In 1893 Riedler served as the head of a delegation of more than a dozen expert engineers dispatched by the Association of German Engineers to write essays on American technology for the Association's journal and as lead investigator into engineering education in the U.S. The results of both studies were published later that year in two books, Mechanical Exploitation of Natural Resources in America [20] and American Technical Educational Institution.[21] Riedler's examination of American engineering education relied on a variety of sources. He used Bureau of Education reports, made campus visits, corresponded with senior engineering professors(including Swain at MIT, Thurston, then at Cornell University, and Arthur M Wellington), and consulted university catalogs and U.S. census material. The study balanced praise and criticism, noting, for instance that many American engineering schools provided inadequate instruction in mathematics and the natural sciences. He believed, furthermore, that the standards for technical drawing were too low.[21]

The substance of the report, however, was a highly positive, 100-page overview of American engineering education. The report examines over 2 dozen engineering programs in at least statistical terms and in greater depth programs at Stevens, Cornell University and MIT. Riedler's highest praise went to programs with the least lecture component and the highest laboratory and workshop content, typically 60:40 or 65:35 split conformed to his ideal. In this context he praised Cornell's laboratories as the best equipped in the world. He was also deeply impressed by the extent of philanthropy in the U.S. enriching universities with gifts and bequests. And despite the unevenness of their educational preparation before they attended universities, American students also impressed him with their receptiveness to hands-on, practical training. "Students born in America and raised in the spirit of the land simply refuse to acknowledge that there is a contradiction between practical work and science," he maintained, and he insisted further that if their preparation was better, American engineering students would be superior to Germans.[21]

The results of Riedler's report came quickly. In 1894 the Association of German Engineers adopted a series of resolutions at their annual meeting in Aachen. The Aachen Resolution were directed to the various state governments in Germany to increase the budgets of technical universities, especially for the purpose of creating teaching and research laboratories in conjunction with private industry. The Resolutions also created the pre-requisite for students that they spend a year before beginning their university educations as apprentices in workshops or factories for the exposure to practical problems.[22]

Historians of German engineering education have largely judged the Aachen Resolutions as the key impetus in reforming the system and implementing most of Riedler's ideals.[23] Riedler later became the head of the Royal Technical University of Berlin's automobile testing laboratory, the first systematic testing facility in Europe. He retired at age 70 in 1920.[24]

Conclusion

In conclusion, the results of Riedler's efforts at the turn of the 20th century to reform German engineering education demonstrated the high quality of American methods in preparing young men and a few young women for careers in engineering, quality held in high esteem by knowledgeable European observers. But this example also shows the convergence of methods in the two most advanced industrial nations of the time. The success of German industrial products in winning awards at the Columbian Exhibition of 1893 gave a boost to the manual training movement in the U.S. to improve the education of secondary schools students along the lines of the German model of technical training.[25] The education of engineers, technicians and mechanics in both countries profited from the cross-fertilization of practices and ideals.

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