Morrill Act's Contribution to Engineering's Foundation

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A century and a half ago the Morrill Act provided grants of federal land supporting research and collegiate instruction in applied science. Although the act addressed "agriculture and the mechanic arts," engineers have not always embraced its significance in the founding of their profession, as have the agriculturists. The act and its proponents deserve recognition for their role in establishing the U.S. as the global center of excellence in engineering education.

Land-grant schools accounted for six percent of the 1,000 schools considered by *U.S. News* in a recent collegiate ranking, yet 47 percent of the top 50 engineering schools owe a debt to the Morrill Act. Furthermore, 57 percent of all Ph.D. degrees granted by the top 50 schools came from land-grant institutions. Not only are land schools disproportionately better quality, but they are simultaneously bigger, leading to a quantitative magnification of their societal impact. Only six sparsely populated states do not find their land-grant school ranked among the top 500 universities in the world, giving 95 percent of our population local access to world-class learning opportunities in the applied sciences. Imagining a university education prior to the act is like trying to envision a society without engineers.[1, 2, 3, 4]

Before the Morrill Act

The French military institute *Ecole Militaire* was perhaps the first organization to institutionalize the application of science, applying mathematical principles to artillery and fortress construction in the eighteenth century. Sylvanus Thayer returned to West Point to lead his *alma mater* in 1817, and was perhaps the most influential American engineering educator in the first half of the nineteenth century. He traveled to France to observe military instruction and purchase books and maps. He hired West Point's first engineering professor, a former Napoleonic gunnery officer, and implemented the French pedagogy of studying math and science prior to more applied courses.

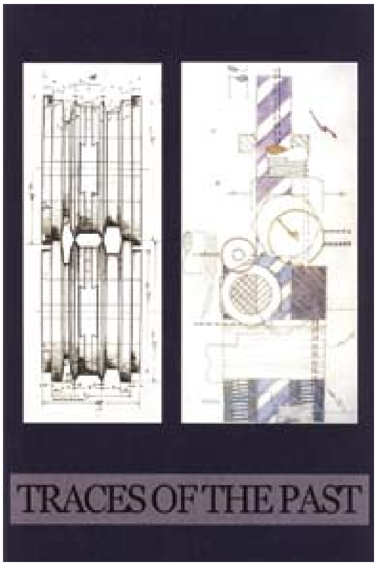
Thayer made no attempt to reconcile his technical curriculum with other contemporary American colleges. Graduates from the military academy formed the technical infrastructure of the young nation. West Point professors wrote mathematics textbooks used throughout the country, and in 1837 Denis Hart Mahan wrote *A Course in Civil Engineering*, that became the English language standard. Historian Stephen Ambrose concludes that under Thayer, West Point was turning out better engineers than soldiers. By 1860 "nearly all the great public works of the country … have been directed by its graduates; they were the pioneers in the construction of railroads … and the great scientific works of the government have been chiefly conducted by them."[5]

West Point was exceptional in the first half of the nineteenth century. The traditional early U.S. collegiate education had changed little from its colonial English origins. Proficiency in the *dead languages* of Latin and Greek figured prominently in entrance requirements, effectively disqualifying all but the most privileged. All colleges had more or less the same curricula, designated by the college president, and instruction was based on recitation of selected texts that were considered to be the final authority in a given subject. The pedagogy and curriculum of the classical mid-nineteenth century U.S. college treated knowledge as static and historical, producing lawyers, ministers, and doctors able to prescribe bloodletting and quicksilver in the twilight of medicine's pre-scientific era, but not the technologists who would put man on the moon a little more than a century later.

Justin Smith Morrill

Science and technology were jointly evolving when the American college was not. Throughout most of history, science and technology developed largely independently. The ancient Greeks viewed earthly realities as debased ideal forms. It was a practical perversion of Euclid's theory to use geometry to solve earthly problems. Unfortunately the enduring influence of the Greeks tended to divorce higher education from practical application for thousands of years. Technology advanced largely outside the university. The book-learned university professors of medicine distanced themselves from operative surgeons, who had more in common with barbers. Universities expelled those who worked with their hands. Men like Galileo and Newton developed both technology to allow more precise measurements and mathematical theory to correlate the empirical with the rational. While both Newton and Galileo received pay from universities, their greatest work was done independently. Thomas Kuhn views the advancement of mathematics, astronomy, and dynamics as more or less a progression toward more complexity from the Greeks onward. Other, more empirical sciences such as chemistry and biology relied on the development of technology—instrumentation—to commence their progression, exploding onto the scene in the nineteenth century.[6]

While the European leisure class was exploring the empirical sciences, the young United States marched to a different drum. With an abundance of natural resources and a shortage of labor, technology was seen as an enabler of low prices rather than low wages as in Europe. The keenly detached Frenchman Tocqueville observed "every new method which leads by a shorter road to wealth" motivated "the grandest effort of democratic people" addicted "to scientific pursuits . . . . In aristocratic ages, science is more particularly called upon to furnish gratification to the mind; in democracies, to the body."[7] While Tocqueville admired American democracy, in his mind there was a dilemma. "Nothing is more necessary to the culture of the higher sciences, of the more elevated departments of science, than meditation; and nothing is less suited to meditation than the structure of American society." [8]



Demand for Practicality

The classical college struggled to incorporate the rapidly expanding empirical sciences into its standard curriculum, while challenged by the particular American demand for practicality. In 1828, members of the Yale faculty issued a report that defended the classical curriculum and suggested how it could be modified to be made more relevant. The classical college's emphasis on literature was justified because its graduates were expected to be successful men in their communities, and such men required eloquence to assume their proper station in society. The classical curriculum was not aimed at advancing nor teaching practical knowledge. "The most gifted understanding cannot greatly enlarge the amount of science to which the wisdom of ages had contributed."[9] The authors of the Yale report inadvertently penned the epithet of the classical curriculum. "A superficial education . . . proposes to teach almost every thing in a short period of time . . . . In this way nothing is effectually taught."[10] As the classical college tried to make room for chemistry, electricity, and biology and the advances in mathematics and physics while retaining its classic literary function, it became superficial.

The solution to the classical colleges' dilemma was to be found in a different European model for higher education. The German university was typically divided into four departments: theology, law, medicine, and philosophy. Professors in a department could lecture on whatever they pleased, and students could attend lectures at their own discretion. The lectures included references to a variety of works, and the student was expected to know the topic rather than the book. The German university was built for "the ardent methodical independent search after truth in any and all of its forms but wholly irrespective of utilitarian application. . . . Its chief task . . . is the development of great thinkers, men who will extend the boundaries of knowledge"[11] in all directions. This dynamic view of knowledge, coupled with the inclusion of natural philosophy and therefore science in the philosophy department, made the German university a better template to include the new empirical sciences than the English college.

Turner and Grass-Roots Agitation

The American colleges did not simply replace the English model with the German; rather they added a key innovation derived from the practicality of the American people. Jonathon Baldwin Turner, a classically educated professor and farmer from Jacksonville, IL, was convinced that new universities were required "to apply existing knowledge directly and efficiently to all *practical* pursuits and professions in life, and to extend the boundaries of our present knowledge in all possible *practical* direction."[12] Turner was looking to professionalize agriculture and the mechanic arts similar to "the divines, the lawyers, the physicians, and the military men" who "have their specific schools, libraries, apparatus, and universities."

By emphasizing books and languages, "the mind is trained to undue deference to the authority of the book, with little capacity to look after the fact." Turner appreciated the limits of the classical college, considering it pedantic "agonism at verbiage," but he did not completely disavow the classics. Turner thought the new industrial universities should either partner with existing classical colleges or add a classics department. Turner was not proposing purely practical vocational schools—they already existed in Europe; rather he was proposing to make college more practical.

The Yale-educated professor clearly appreciated the practical application of theory, observing there are "more recondite and profound principles of pure mathematics immediately connected with the sailing of a ship, or the moulding and driving of a plow, or an axe, or a jack-plane, than with all three of the so-called, learned professions together." Just as he rebutted the classical Greek separation of theory and practice, Turner addressed their contemporary apologists at Yale. Instead of eloquence to be used upon attaining an influential position, "the effort should be made to make each man an intelligent, thinking man, in his own profession in life, rather than out of it." He consistently included the mechanic arts along with agriculture when describing practical studies. Although most of the nation's citizens were farmers, "the interest of mechanics and mechanical institutes and associations. . . is no less intelligent, marked and decisive, than that of their agricultural brethren, although they have fewer organs and advocates."

Turner sought to fund his new colleges with the sale of federal land. During 1851-53, Turner agitated throughout the state of Illinois, and eventually in 1854 the state legislature petitioned the U.S. Congress for support of his plan calling for a national "system of Industrial Universities . . . cooperative with each other . . . for the more liberal and practical education of our industrial classes." The practical universities were to be funded by a donation of not less than 500,000 acres of public land to each state. Turner's work received national recognition and much attention in the East Coast press. The educated farmer from Illinois anticipated sectional opposition to his proposal by "untaught farmers who devote all their capital and hired labor to the culture on a large scale, of some single product, which always pays well when so produced on a fresh soil, even in the most unskillful hands . . . . This class is, however, generally the last friends of education."

Jonathon Baldwin Turner was not the first to suggest funding higher education with proceeds from federal lands. The precedent for that, although somewhat inconsistent, can be traced to the Northwest Ordinance. Rensselaer Polytechnic Institute was experimenting with practical education, and Brown and Michigan were incorporating the German model into their curriculum. Turner was the first, however, to incorporate the concepts of practical education funded by land grants into a national system of research-oriented universities, and he clearly intended them to teach engineering.

Morrill and Congressional Debate

Justin Smith Morrill grew up the son of a Vermont blacksmith. Rather than attend college, he clerked at a store and became self-educated through a voracious reading habit. Eventually Morrill was made a partner in the store, retired to farm as a relatively young man, and was drawn to politics. He was elected to congress the same year that Turner's petition from Illinois was presented. Two years later in 1856, Morrill introduced a resolution to begin study of "establishing one or more agricultural schools, upon the basis of the naval and military schools,"[13] conspicuously omitting the mechanic arts.

In another two years in 1858, Morrill presented his first attempt at a comprehensive land-grant bill to the 35th Congress. The act provided for 30,000 acres of western federal land to be apportioned to states for each congressman and senator. Populous eastern states such as New York and Massachusetts would receive more land than Iowa and Minnesota. The states would be issued paper scrip that could be sold on the open market. Administration and selling costs would be borne by the states themselves. The states were to invest the capital, and the proceeds would be used to establish or maintain "at least one college where the leading object shall be, without excluding other scientific and classical studies, to teach such branches of learning as are related to agriculture and mechanic arts, in such manner as the legislatures of the State may respectively prescribe, in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life."

By accepting the grants, the states agreed to compensate the college fund for any investment losses in capital. Although the money could be used to purchase land for experimental farms, it could not be used to erect buildings. If the states did not begin practical instruction within five years of receiving the grant, they would have to repay the federal government. Finally, each college was to issue an annual report "recording any improvements and experiments made . . . to all other colleges which may be endowed by the provisions of this act."[14]

Morrill was a free-soil whig from New England, and, like much of the legislation in the 1850s, his act was opposed more along sectional than party lines. During this decade the federal government was often dysfunctional, as congress grappled with assimilating the vast territories acquired by President Polk in the context of slavery. Morrill anticipated a constitutionally based opposition to his bill and stated "the power of Congress to dispose of the public lands at its discretion is plain, absolute, and unlimited" with the only condition that it be "for the common benefit of all the states." The meaning of the word dispose was continually debated, and the southerners rejoined with a tortured definition that precluded giving away or donating the land. There had been occasional grants of land for educational purposes in the West, and more recently there were generous land grants to encourage railroad construction in the 1850s. Opponents of the act drew a distinction of responsible stewardship between these measures, which would have the effect of increasing the value of the surrounding federally owned lands, and the Morrill Act, which would dump land on the market, thus devaluing the remaining federal lands.

The precedent for funding higher education with federal land was inconsistent, but the most recent was also the most definitive as the 35th Congress considered Morrill's bill. The 33rd Congress had passed legislation to fund insane asylums with land grants. In his veto message, Franklin Pierce said that "it is wholly immaterial whether the appropriation be in money or land," the real issue is that if the congress had the power to fund insane asylums, "it has the same power to provide for the indigent who are not insane, and thus to transfer to the Federal Government the charge of the poor and insane from all the States." Pierce explicitly considered that measures for schools for the insane could be extended to more typical schools, specifically universities. He noted that the original constitutional convention considered a proposal to empower congress to establish a university in the District of Columbia. "All matters of this nature. . . were not comprehended, either expressly or by implication, in the grant of general power to Congress; and that, consequently, they remained with the several States." Extending Pierce's argument in the 35th Congress, Senator Clement C. Clay from Alabama argued since the Constitution goes no further than to protect inventions through patents, it "is tantamount to the denial of such power, for it expresses a different way by which to patronize art and science."[15]

The Spirit of the Land Grant College: This mural adorns the wall above the entrance of the HSSE Library at Purdue University. The mural, a gift from Mr. and Mrs. Walter Scholer and Mr. and Mrs. Robert B. Stewart, visually presents the contribution of the land-grant colleges to American higher education. It was dedicated in a special ceremony on October 2, 1961.

The South's constitutional objections to Morrill's proposal were more tactical than ideological. They feared any general expansion of federal government powers that would provide a precedent for federal interests regarding their peculiar institution. Senator Williamson Cobb from Alabama argued that "various, and even conflicting habits, customs, and local interests, in the different states, will be protected by their Legislatures," and if the federal government "keeps within its appropriate sphere, the prosperity of the States will be secured, and the interests of the Union will be enlarged." Senator Clay narrowed the general argument to education stating that the people would never "surrender the supervision, control, and direction of their education to the Federal Government."[16] Mr. Mason from Virginia asked if federal assets were used "to establish agricultural colleges . . . would it not be in the power of a majority in congress to fasten upon the southern states that peculiar system of free schools in the New England states which I believe would tend . . . to destroy that peculiar character which I am happy to believe belongs to the great mass of the southern people."[17]

Democratic Access to Higher Education

Senator James Harlan of Iowa was continually an eloquent and prescient proponent of the Morrill Act. Reminiscent of Turner, he responded to Mason by noting "there may be those who are not disposed to give the means for the development of the minds of the masses; those whose interest it is that the laboring men of the country should be ignorant, should be uneducated and dependent, that their sweat and their toil may be used to advance the interests and to promote the happiness of those more highly educated and refined; it may be that it is a blessing to Virginia that she is now more largely represented by adult white people who are unable to read and write, in proportion to her population than any other State of the Union; it is a blessing, however, that the people of my State do not covet."

The bulk of Justin Morrill's defense of his act revolved around the issues of fair democratic access to higher education and the utilitarian benefit the Union would receive from such support of agriculture. In 1858 Morrill estimated there were five-million people of sufficient age to attend college, and the 239 existing colleges taught 27,000 of them. At that time, only 100,000 were employed by the classic professions of law, medicine, and clergy. Thus, the classical colleges were educating only a small percentage of the nation's youth and still were providing far more graduates than the nation could use.

Morrill went to great lengths to document that United States' agricultural practices have produced exhausted soil and declining crop yields. Meanwhile, modern farming practices in Europe had produced better yields on soil cultivated for many generations. With the overwhelming majority of the nation employed by agriculture, the country as a whole would receive utility from a national investment in agriculture education and research.

Supporters of the act revived an argument first presented by Virgil Maxcy of Maryland in 1821 regarding fairness between states. "The original states of this union, by whose common sword and purse those lands have been acquired," deserve an appropriation of land similar to the western states "for the endowment and support of literary institutions, within their own limits."[18]

Morrill's arguments were persuasive, but were they genuine? Senator Clay fairly warned "agriculture is the mere name by whose potential charms the people are to be defrauded of their rights. The promotion of agriculture is but the incident, not the great object of this measure . . . it authorizes instruction in all scientific and classical studies, and that the object of the donation is not to qualify men for agriculture, but to promote the liberal and practical education of the industrial classes in all the several pursuits and professions of life."[19]

Morrill's position regarding the mechanic arts was not as clear as Turner's. It is quite possible that it was politically expedient for him to concentrate his arguments on the benefits to agriculture, knowing that opposition to his bill was from agricultural southern and, to a lesser extent, western states. Still, Morrill's arguments based on utility and fairness often could be turned against the inclusion of mechanic arts. "Our engineers are doomed to no merely local fame. Our agricultural implements are beyond the reach of competition. Yet, while we may be in advance of the civilized world in many of the useful arts, it is a humiliating fact that we are far in the rear of the best husbandry in Europe." He continued: "There is not a class of our community of whom we may be so justly proud as our mechanics. Their genius is patent to all the world." When comparing governmental aid to agriculture and the other industries, Morrill claimed that "we secure ingenious mechanics high profits by our system of patent rights," and similar advantages are given to manufactures and commerce, but when agriculture appears "we coldly plead there is nothing left for her."

A newly elected Justin Morrill suggested strictly agricultural colleges even after Turner's 1854 Illinois petition to congress had included the mechanic arts. In the debate Morrill did not view the mechanic arts as deficient or neglected in the U.S. as compared to agriculture, and he did not make corresponding utilitarian arguments to justify inclusion of the mechanic arts in his bill. His strongest arguments were particular to agriculture, and yet the mechanic arts were specifically included. One cannot know the motivation of Justin Morrill. It seems fair that he wanted to support practical collegiate education for the industrial classes and simultaneously strengthen the nation. "National wealth is greatly increased or diminished by the more or less skill, dexterity, and judgment, with which labor is generally applied. As legislators, we can have no subject before us of higher intrinsic importance."[20] Morrill, as almost any of his contemporaries, could not have anticipated how greatly his bill would help shape the engineering profession. Turner, the Yale-educated classical professor-turned-farmer, perhaps caught a faint glimpse. It seems likely that both Turner's vision and Morrill's political acumen were required to produce the legislation supporting land-grant schools.

With much debate Morrill's bill narrowly passed congress in 1859. After sending mixed signals, President Buchanan vetoed the measure. With an override impossible, Morrill needed a sympathetic president or a less-divided congress. He was to find both with Abraham Lincoln's election and the southern secession, and largely the same bill easily passed congress and was signed into law on July 2, 1862. The previous day President Lincoln signed a bill financing the transcontinental railroad with land grants, and less than two months earlier he signed the Homestead Act using land grants to encourage western settlement. It is simply astounding that a government could enact such far reaching legislation at a time when its armies were fairing so poorly in the Civil War.

Implementation

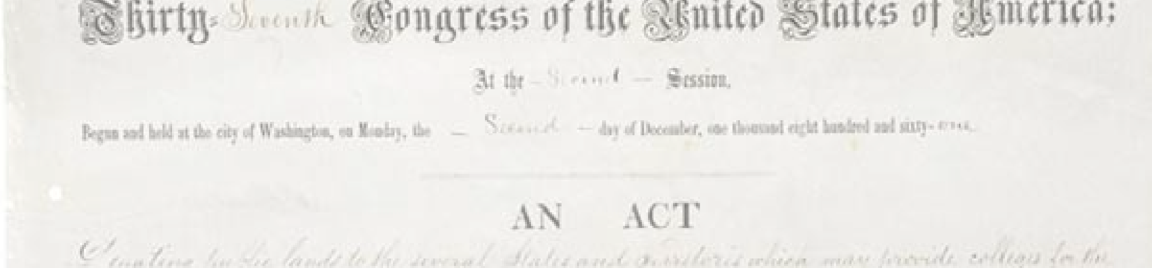
Immediately after the Civil War, engineering education exploded in the U.S. In 1866 there were only 300 men with engineering degrees, and only six colleges of any reputation granting them. By 1870, led by the newly created land-grant institutions, there were 21 colleges granting engineering degrees, and the total number of graduates was 866. In the 1870s an additional 2,249 engineers graduated, and in the first decade of the 20th century 21,000 engineers joined the work force. By 1911 the U.S. was graduating 3,000 engineers a year and had a total of 38,000 engineers in the work force. By comparison, Germany graduated 1,800 practicing engineers each year. In just 50 years after the passage of the Morrill Act, the U.S. had become the quantitative leader in technical education.[21, 22]

The Morrill Act provided incentive for instruction in agriculture and mechanics, but did not completely fund the activity. State and private funds were necessary to augment the federal money, and subsequent federal grants were made in support of the land-grant mission. The Hatch Act of 1887 established an annual federal subsidy for agricultural experiment stations. There was popular agitation for the stations to provide immediate practical results to farmers, but some university administrators such as George Atherton at Pennsylvania State University used the funds to extend the underlying basic sciences. A second Morrill Act was passed in 1890 to augment the original grant. In sum, by 1905 the federal government provided the University of Illinois with $73,000 in annual support, while the state contributed $400,000.[23] Each land-grant school was the result of a unique partnership between the federal, state, and local governments and private benefactors.

The Morrill Act allowed the engineering schools to innovate while restricting them from making common mistakes of the era: speculative investing of funds and excessive expenditures on bricks and mortar at the expense of laboratories and teachers. In the half-century after the Morrill Act passed, engineering became a key component of land-grant universities. As this occurred, the land-grant schools largely determined how modern engineering emerged from the mechanic arts. At Cornell, Andrew D. White "suggested the establishment of fully equipped mechanical laboratories and workshops in connection with the department of mechanical engineering." Later. White urged the formation of the first department of electrical engineering in the U.S.[24]

In 1903 Illinois established the first engineering experiment station, modeled after the agricultural stations of the Hatch Act, but funded by the state. Funding of the station allowed labs and equipment to be purchased and emphasized the research function of the department. President Andrew S. Draper said the large appropriation for engineering was due to the rapidly increasing enrollment, and "to the very cordial cooperation of the organizations and the business men engaged in the building and the constructive business in the state."[25] By 1915 this atmosphere had resulted in many advancements in engineering, and perhaps the two most far reaching were the development of steam tables and quantification of concrete as a construction material. As influential as these developments were, the overall research activity of the university was valued by the Illinois taxpayers for its agricultural work, making legislative support of the institution popular. Although industry was increasingly reaping the benefits of the land-grant schools, they remained popularly supported as if they were fully dedicated to agriculture. Perhaps 50 years later, agriculture continued to be the political "incident, not the great object," of the land-grant schools.

Because of the fruitful ambiguity of the Morrill Act, the colleges were able to innovate their curriculum. In 1870, more than two and a half years of the four-year engineering curriculum were typically common to the liberal arts



courses in the classical curriculum, including physical sciences, mathematics, and the humanities. By 1915 this liberal component was reduced to something like one and a half years. Most significantly, foreign languages went from over an eighth of the total to near insignificance. The U.S. by now was generating its own technical literature, and it was no longer necessary to read French. The resulting balance was applied to technical courses in the major engineering branch, signifying a trend toward greater specialization.

The land grant college on a Capitol ceiling fresco. U.S. Capitol, Washington, DC

Also, during this time period drawing and shop classes were reduced as the "mechanic arts" of the Morrill Act were redefined to more closely resemble modern-day engineering. Economics replaced history and political science as the preferred social science of engineers foreshadowing the synergy between engineering and industry that became manifest in the following century. Laboratory instruction became a dominant component of engineering instruction, led by the rise in importance of mechanical and electrical engineering, as opposed to military and civil engineering.

Despite southern fears of centralized higher education policy, the Morrill Act allowed significant innovation at the local level that enabled engineering to evolve into something similar to its final form by World War I. When federalism works best, it defines broad policy objectives and provides supporting funding. State and local governments must provide the bulk of the funding and oversight. The state of engineering education in the U.S. today can be attributed in no small measure to the successful application of federal principles of government displayed in the formation and implementation of the Morrill Act.

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