Reinventing the Philosophy of Graduate Engineering Education

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A significant confluence of forces that prevailed in shaping a vast expanse of the historical landscape of America in the middle of the nineteenth century also invaded the American academe and brought about the development of the graduate school in the United States. Such convulsive forces as the democratization of access to American colleges, the emancipation of education from the dictates of religion, the expansion and diversification of the collegiate curricula to include courses addressing the practical needs of agriculture and the mechanical fields, the Morrill Acts of 1862 and 1890 and the significant influence of the German universities on creative scholarship and original research crystallized a unique philosophy for the American graduate school that not only satisfied the calling for advance education at that time, but has also endured through the decades, successfully leading America into the age of modernity, and will no doubt continue, if allowed, to lead the United States even beyond the dawn of the 21st century. The philosophy of American graduate education, however, ought to be perceived as neither fixed nor immutable, and is as relevant and as effective only as it is in conformity with the new array of dynamic forces that inexorably shapes and molds it. In view of the powerful and modern forces that have come to play in the global arena more than a century after the establishment of the American graduate school, it is only propitious, especially at the twilight of the 20th century, to examine our current, hereditary philosophy of graduate engineering education, and how such a philosophy, in the face of a vastly altered world, must be reimagined and reinvented.

A Formative Philosophy

The same fundamental philosophy of graduate education runs operative in all major fields of study in the United States, the field of engineering included. While the establishment of the first graduate school in the United States did not happen until 1876,1 it is instructive to examine the reigning academic philosophy in the colonial colleges in early America since it not only immediately predated the academic philosophy of the graduate school in the United States, but also, in fact, precipitated the latter's invention as well as the latter's eventual and persisting dominance in American higher education, even today.

The principal goal of the colonial colleges in America, of which the classic archetypes include the Colleges of Harvard, Yale and William and Mary, among others, was to bring about a translatio studii,2 that is, a transfer of higher learning and intellectual culture from the Old World to the New World. With the christian tradition considered to be the core element of this transfer of
learning, the main aim of the colonial colleges was more specifically the education of orthodox clergy and orthodox laymen.

Thus, the earliest printed rules of Harvard College promulgated that "Every one shall consider the Mayne End of his life & studyes, to know God & Jesus Christ, which is Eternal Life." Similarly, Yale was decreed in 1701 to be a place "wherein youth may be instructed in the arts and sciences, who through the blessings of Almighty God, may be fitted for public employment, both in church and civil state." The College of William and Mary was established with a view to providing the Church with religiously educated youth of good letters and manners, and also to propagate Christian faith among the Indians.

The typical curriculum of the colonial colleges was designed to consist heavily of the classical languages and literature together with Hebrew, ethics, politics, physics, mathematics and divinity. Leading to the four-year bachelor's degree, the curriculum which was basically copied from those of the colleges of Oxford and Cambridge was implemented rigidly without any regard for the academic interests and professional plans of the individual students. Such academic inflexibility was justified based on the belief that there was a fixed body of knowledge, the "liberal arts," which had been transferred from antiquity through the Middle Ages, Renaissance and Reformation, that constituted absolute truth, and which must be absorbed, and not criticized or questioned, by the students. It was also generally believed at the time that knowledge of the classics was a badge of gentility and a sine qua non for the practice of the professions of law, medicine and theology. Hence, in conferring the bachelor's degree, Harvard College laid down in its laws of 1642-1650 the following formal requirement: "Every scholar that on proofe is found able to read the originall of the old and New testament into the Latin toungue, and to Resolve them Logically withall being of honest life and conversation and at any publicke act hath the approbation of the overseers, and master of the College may bee invested with his first degree." It is apparent that the colonial colleges in early America had as their chief aim the preservation and conservation of existing knowledge, rather than the search for or the generation of new knowledge. Their concern was more the forming of the character of their students through their prescription of a classical curriculum. It was with this formative philosophy of higher education that the colonial colleges in America continually trained a special elite for ecclesiastical and civil leadership, and continued to do so with the same academic philosophy for nearly 200 years.

A Scholastic Philosophy

The transition period from the era of the colonial colleges to that of the true universities in America was fraught with tumultuous battles of volition, beliefs and ideologies. In the end, a decisive metamorphosis in academic philosophy took place, leading to the establishment of the American universities which at the time generally connoted an educational institution of large size and providing advance instruction in all the main branches of learning. Ultimately, the American graduate school was founded, possessing an altogether new brand of academic philosophy.
A widespread dissatisfaction with the traditional liberal-arts colleges in America started fomenting in the second quarter of the nineteenth century owing to the narrowness and rigidity of the colonial college's prescribed curriculum in addition to their failure to address the practical needs of farming and mechanical arts of a rapidly growing society. The rising popularity of the rationalism and empiricism of the Enlightenment elevated the value of the natural sciences, and helped incite the movement to expand the collegiate curricula to include new subjects including Newtonian science, Cartesianism, modern English and history. Converging with these academic currents is the steadfast belief of the Enlightenment and of the American and French Revolutions that social institutions can be reshaped to a more just order through proper governmental action. Thus, the gaining of American political independence catalyzed the demand that education be made available to the masses, and that it must not be confined to an elite. Enlightenment principles also helped instigate the emancipation of education from sectarian control.12

The campaign for a more egalitarian and utilitarian educational institution in America began most conspicuously, perhaps, with Thomas Jefferson. With the founding in 1825 of the University of Virginia, America's first real state university, Jefferson insisted on the freedom of the students to select their own courses to be able to specialize, and asserted the secular and nondenominational orientation of this first fully public university.13 In the 1850's, the agricultural press and various local and national agricultural societies joined forces to demand the establishment of what were called "democracy's colleges."14 Evan Pugh of Pennsylvania15 and Jonathan Turner of Illinois16 played major roles in galvanizing public sentiments in favor of such project. In 1862, President Abraham Lincoln signed the Morrill Act, which was introduced by Justin Morrill as a bill in Congress in 1857, providing for federal aid to agricultural and mechanical colleges.17 The passage of the second Morrill Act of 1890 significantly increased the amount of federal aid to these land-grant institutions.18 The Morrill Acts of 1862 and 1890 helped provide the resources for the establishment of more state universities all over the United States.

Emulating the Jeffersonian example, the leading colonial colleges in America began to welcome academic changes, incrementally over time and not without fiery debates. George Ticknor, a professor of modern languages at Harvard, succeeded in 1825 in convincing the college corporation to reorganize the Harvard faculty into distinct departments of study and to permit upper classmen a limited number of electives.19 In 1837, Ralph Waldo Emerson continued to demand for change by pronouncing in his famous address at Harvard, "The American Scholar," that education ought to be adapted to the individual, rather than vice versa.20 By 1839, the Harvard faculty had agreed to permit students, after the freshman year, to substitute subjects such as science, modern languages and history for required Latin and Greek.21 Still, in 1850, the president of Brown University, Francis Wayland, criticized the lack in the United States of institutions "designed to furnish the agriculturist, the manufacturer, the mechanic, or the merchant with the education that will prepare him for the profession to which his life is to be devoted."22 In similar vein, in 1851, Henry Philip Tappan,23 elected president of the University of Michigan, proffered his conception of the ideal university as a place of "free and independent study where knowledge is the object, and culture the necessary attendant."24 Then in 1869, Charles W. Eliot, a 35-year-old elected president of Harvard, decreed to provide Harvard
students with three essentials: (1) freedom of choice in studies; (2) opportunity to specialize in a
given field of study; and, (3) a curriculum design which places on the student the responsibility to
guide his conduct. By 1874-1875, Eliot confined all Harvard required courses to the freshman
year with the exception of rhetoric, philosophy, history and political science. Electives were
extended to freshmen in 1883-1884 and, in 1895, the remaining required courses for freshmen
were reduced to two English courses and a modern foreign language. Numerous colonial
colleges subsequently followed the lead of Harvard, and reworked themselves into becoming true
American universities.

While new state universities were being established and the old colonial colleges were being
reorganized, technical institutes were being raised in many parts of the country. In 1824,
Rensselaer Polytechnic Institute was founded in upstate New York to become the first separate
technical school in the United States. In 1835, courses in civil engineering were introduced to its
curriculum which previously had emphasized agriculture. Soon, eight graduates earned bachelor
degrees in civil engineering, the first to be granted in the United States. In 1849, Rensselaer
broadened its curriculum to include architecture and civil, mining and topographical engineering.
With engineering rapidly becoming an independent discipline, a number of liberal-arts colleges
established technical schools and departments. Union College founded in 1845 a department of
civil engineering, Harvard established in 1847 the Lawrence Scientific School, Yale instituted in
the same year a new department which later was to become known as the Sheffield Scientific
School, Darmouth founded in 1852 the Chandler Scientific School, Brown in the same year
organized a department of practical sciences and, in 1855, the University of Pennsylvania created
department of mines, arts and manufacturers. The Massachusetts Institute of Technology
opened in 1865, providing a full course of scientific instruction and laboratory investigations for
prospective engineers and technicians. It should not be forgotten that the United States Military
Academy at West Point, founded in 1802, placed its main emphasis on the training of engineers
after 1817. The American Literary, Scientific, and Military Academy, a civilian school founded
in 1819 in Vermont, also trained soldiers and engineers.

Thus, the demand for the democratization of American education, among others, eventually led
to the establishment of true universities in the United States, with the concomitant privileges of
expanded, utilitarian curricula, availability of elective courses and the freedom of universities
from sectarian control. Thus, the "horizontal expansion" of American higher education was
accomplished, and the time was propitious for its "vertical expansion" through the development
of the American graduate school.

The decades following the Civil War witnessed an America that was emerging to be more
industrialized, urban, specialized and secular. With American academicians, in light of the
experience of the Civil War, acknowledging, once and for all, the professional respectability and
social indispensability of the engineer, the natural scientist and the industrial technician, a
demand for a new kind of higher education was recognized. Concurrently, the prestige of the
German Ph.D. degree continued to increase among academic careerists, and the pilgrimage of
American students in German universities grew proportionately. Thus, the gates for ushering the
influence of the German university into the American institutions of higher education were thrown wide open.

The quintessence of the German university, whose epitomes included the Universities of Berlin (founded in 1810), Breslau (1811), Bonn (1818) and Munich (1826), was the objective pursuit of truth through original investigation or scientific research. It emphasized the concept that a true university must preserve the freedom of teaching and the freedom of learning. Freedom of learning (Lernfreiheit) meant that the students should be able to take whatever courses they choose, and freedom of teaching (Lehrfreiheit) meant that the professor should be able to investigate any problem in the conduct of his research and to reveal whatever findings he may have in teaching and in published works. Employing novel instructional techniques in training scholars, including the seminar, the specialist's lecture, the laboratory and the monographic study, the German university succeeded in welding teaching and research to produce the creative scholar and the original investigator in every academic discipline.

The ideals of the German university were the instruments and tools that built Johns Hopkins University in Baltimore in 1876 to become the first true American graduate school. Nonsectarian by design and aimed at national, rather than local, influence, Johns Hopkins was dedicated to the unimpeded search for truth, and, through the effort of its first president, Daniel Gilman, attracted a group of faculty of "the ablest minds." The methods of instruction were patterned after those of the German university, including lectures to large groups, a few seminars for intensive research and laboratories for experimentation. With the pioneering impact of Johns Hopkins University on the merging of teaching and research, older American universities, including Harvard, Yale and Columbia, followed to adopt the German university's ideal of combining teaching and original research. The new universities that were founded in the latter part of the nineteenth century also patterned their graduate schools after the academic blueprint of Johns Hopkins. These universities included Clark University, the Catholic University of America and the University of Chicago.

Thus, the American graduate school, formed at the intersection of a democratized American education and the German university's combination of teaching and original research, secured for itself a scholastic philosophy of graduate education. This academic philosophy provides for the student: first, the freedom to be an individual with the independence to make his own choices and; second, the freedom to pursue new knowledge, wherever such pursuit may lead and whatever facts such pursuit may yield. It boldly realizes Eliot's view of providing the individual with "the highest development of his own peculiar faculty" and Emerson's desire for "the single man plant[ing] himself indomitably on his instinct, and there abide . . ." Finally emancipated from the old and limiting burden of the colonial colleges to conserve the genteel tradition of the past, the American graduate school equipped itself with the torch of specialized scholarship and helped America navigate itself through a century and into the twilight of the twentieth century.

An Integrative Philosophy
The freedom to choose and to pursue a specialized line of knowledge, however, appears proving to be a two-edged sword. While individualized engineering research, on one hand, proved to be of tremendous benefit to a relatively young and growing utilitarian society, it could, on the other, result in advanced knowledge that, in the midst of a globalized economy, is discrete, compartmentalized, isolated and, thus, is unconsummated. While the formative philosophy of the colonial colleges molded a genteel tradition that was based on classical languages and literature, it appears that the current, hereditary scholastic philosophy of the American graduate school may be spousing another form of genteel tradition that is based, not on classical knowledge, but on unconnected and hermetic individualism. With the local and national boundaries that normally contain the flow of commerce and information continually being obliterated everywhere, a highly globalized, and interdependent, economy continues to spread its dominance and exert its influence on every aspect of business, industry and ordinary life. And just as formative philosophy alone proved inadequate in transforming the colonial colleges into the true universities of the nineteenth and twentieth centuries, it seems clear that scholastic philosophy alone is equally insufficient to usher the American graduate school into the complex and interactive economic arena of the 21st century. A more encompassing, connective and integrative philosophy of graduate education is called for, and especially in the field of engineering.

Contemporary graduate engineering education prototypically consists of the two elements of graduate research and graduate instruction. The implementation of the integrative philosophy to graduate engineering education does not call for the jettisoning or replacement of these two elements; what it mandates are the modification of the manner of conduct of graduate research and the deliberate widening of the conventionally narrow breadth of graduate engineering instruction. The following two approaches are proposed: (1) the introduction of the team approach to graduate research; and (2) the inclusion of professional engineering studies in graduate instruction.

The team approach to graduate engineering education offers an interactive research structure that aims to meet the new demands for a connected engineering scholarship. This team approach is different from, and should not be mistaken with, the teaming of graduate students in a graduate course to complete a common class project. This research-training approach denotes the teaming of two or more graduate students for the express purpose of addressing a common research problem, and producing, based on that shared problem, either individual graduate theses, a thesis for each student, or a single, collective graduate thesis for all the student members within the team. The team may be: (1) intradisciplinary, consisting of two or more engineering students from only one engineering discipline; (2) homogeneously interdisciplinary, consisting of two or more engineering students from two or more different engineering fields; or (3) heterogeneously interdisciplinary, consisting of engineering student(s) and students from non-engineering disciplines. The team approach, by design, will provide an interactive research structure that will not compromise or imperil the training of each participating graduate student for independent research since the nature and scope of the contribution of each team member in the solution of
the research problem will be established a priori. What the team approach will accomplish is produce competent engineering scholars, each of whom is an interactive player, a connected problem solver and an original investigator who will be cognizant of how various and diverse parts work together as a connected whole in the real world. This new research-training approach is cooperative, interactive and integrative.

The aim of the inclusion of professional engineering studies in graduate instruction is to furnish graduate students with a holistic and integrated view of a given branch of engineering within the framework of its industry in local, national and global contexts. This may involve case studies of engineering industries, examining how they operate, interact and connect with various subsystems within a globalized economy. Also to be provided to graduate students are the fundamentals of engineering business, including financing, marketing, planning, management, intellectual property, strategic alliance and technical entrepreneurship.

The advanced world of engineering in the 21st century will certainly continue to require original scholarship and an equal measure of the ability to conduct independent investigation. Originality and independence alone, however, though still necessary, are no longer sufficient to harness the diverse offerings and opportunities of a globalized 21st century. The mature graduate engineer of the future is one possessing a comprehensive vision and an integrative grasp of a global universe and who, in cooperation with other experts, is able to frame relevant solutions that are both effective and informed.

Johns Hopkins University was revolutionary in 1876 because it embodied the American graduate school whose concerns were national, not local, in both nature and scope. The scholastic philosophy of graduate education was all that was needed to address those national concerns. Tomorrow's world, however, is a world of moving and fragile boundaries, economically, politically, socially and culturally. The problems of the world are the problems of America, and the problems of America are the problems of the world. Just as the colonial colleges were compelled by national forces to be transformed into true American universities, American universities today, in both essence and purpose, are being transformed into true global universities, with their aims and concerns being global, not just national. An integrative philosophy of graduate education provides the solid groundwork for this new academic paradigmatic shift. This is the second wave of transformation in American higher education, and the future begins anew.

**Literature Cited**

18. Brubacher et al., op. cit., p. 66.
26. Ibid., pp. xlii-xliii.
27. Brubacher et al., op. cit., pp. 63-64.
35. Brubacher et al., op. cit., pp. 181, 185-188.
36. Morison, op. cit.
37. Emerson, op. cit.

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