The WPI Bachelor of Arts degree in "Liberal and Engineering Studies"

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Abstract
Worcester Polytechnic Institute has recently introduced a BA degree in Liberal and Engineering Studies. The program is intended to provide a curriculum rich in the data collecting, design, and problem-solving outcomes of engineering for students planning careers in fields where such analyses will be invaluable—legal, medical, management, financial and even (we would all hope!) political. The rationale for the degree and the program requirements are discussed below.

Introduction

A modern reader of Agricola's treatise on mining and metallurgy, *De Re Metallica* written in the fifteen hundreds [1], cannot help feeling that many contemporary issues then are still relevant today. In addition to technical problems, pollution, deforestation, and legal issues are still of concern. Of course, there are differences. Agricola favored mining in spite of the environmental damaged inflicted. However, the most startling difference is the Introduction, where Agricola discusses the importance of mining for human societies. The argument that human societies require minerals is easily appreciated by the modern reader, but Agricola's appeal to the opinions of literary authorities and ancient writers would be completely out of place in a modern discourse on his subject. To him, however, the technical topic of his treatise and the philosophical speculations he quotes are an interrelated part of the human enterprise and as a scholar he is familiar with both sides of the issue.

Today we have come to accept that educated people are divided into many disciplines that have little in common. It is entirely acceptable that a humanistic scholar knows nothing about mathematics, science, or technology, and it is not just accepted but expected that technologically trained people have little appreciation of cultural and humanistic values. This compartmental mentality occurs when the world is being changed rapidly by science and technology, and when the implications of these changes affect us more profoundly than ever before. A few examples will suffice: the automobile and modern highways allow us to reach distant towns in a matter of hours and airplanes take us to the most distance parts of the planet in less than a day; modern telecommunications allow us to talk instantly to essentially everybody in the world; the Internet lets us get immediate information on literally anything; we live longer and better than at any time in history and—of course—there are more of us than ever before.

The globalization of the economy has further amplified the impact of technology on modern societies. The connectivity provided by the Internet has generated new markets for products and services, but it has also made available labor that is often both educated and cheap. This is likely to have profound impact on the distribution of wealth in both the developed and the developing part of the world and may, in particular, alter the socioeconomic structure of countries where the general well being of the population is taken for granted. That education plays a role in the prosperity of nations is not debated, but many authors, like Landes [2], argue that it is specifically the presence of both knowledge and know-how that determines how well off societies are. The United States has always been a country where know-how, the harvesting of knowledge for the betterment of life, has been highly valued, and there is a well-justified belief that Yankee-ingenuity will be able to counter any challenges and preserve our way of life.

There are, however, reasons for concern. The demand for engineering majors is high, as demonstrated by the fact that engineering majors receive some of the highest starting salaries offered to graduates with bachelor degrees and immigrants provide the only means to meet the needs for people with advanced engineering degrees, but the US production of undergraduate degrees in engineering has remained essentially constant for several years. Of the over 1.2 million Bachelor degrees conferred in the USA during 2000-02 [3], only about 5% were in engineering, as compared to 9% in Japan [4] and 45% in China. At the graduate level, the numbers are much more favorable [5], and a large influx of foreign individuals, many establishing very successful companies, have largely offset the relatively modest interest in technology by the native born U. S. population. The development of the educational infrastructure in other countries and the increasing economic opportunities are, however, likely to make importing the needed talent an unreliable long-term solution (and subject to short-term disruptions). Thus, increasing the number of technologically trained individuals is—as often pointed out [6]—one of the grand challenges of U. S. higher education.

Not everyone, however, wants to become an engineer and, in particular, leaders of government, non-profit and for-profit organizations are typically educated in non-engineering disciplines. Yet increasingly these leaders would benefit from more technological grounding. This need is the impetus behind the degree in Liberal and Engineering Studies at the Worcester Polytechnic Institute. The degree is designed to provide an opportunity for students who want a broad background in engineering and other disciplines, as preparation for further studies in other fields such as medicine, law, public policy, international studies, business, or wherever a solid technical background would give them a unique edge.

• an ability to formulate and solve problems requiring knowledge of both technological and societal/humanistic needs and constraints
• an ability to apply, as needed, the relevant fundamentals of mathematics, science, engineering, social sciences, and the humanities to solve such problems
• an ability to use the techniques, skills, and modern tools necessary for professional practice
• an ability to function on multi-disciplinary teams
• an understanding of professional and ethical responsibility
• an ability to communicate effectively in oral, written and visual modes
• a recognition of the need for, and ability to engage in, life-long learning, in response to the ever-increasing pace of change affecting societal needs and opportunities
• the broad education necessary to understand the impact of professional solutions in a societal context, both locally and globally.

Table I. The Learning Outcomes specific to the WPI Liberal and Engineering Studies program

Program Objectives and Learning Outcomes

The new BA in Liberal and Engineering (LES) Studies at WPI is designed to offer flexibility beyond what is generally available in traditional ABET accredited engineering programs. The broadness of the program, coupled with the emphasis on creativity and problem solving, should prepare students for many other high-level careers, such as in medicine and health care, law, especially patent law, technology policy, finance, technology management, International relations, public affairs and political service, performing arts, especially music and theatre, and consulting.

The LES program is consistent with the WPI Mission and Goal Statements and Statement of Values for Undergraduate Education as well as with the WPI Undergraduate Learning Outcomes [7]. The learning outcomes specific to the Liberal and Engineering Studies degree program, articulate the abilities for a graduate of the WPI BA in Liberal and Engineering Studies. These outcomes, listed in Table I, are inspired by ABET's Engineering Criteria 2000 [8].

The LES program will offer considerable curricular flexibility to accommodate a wide range of student interests, but at the same time will require students to be intentional about developing a *coherent program of study* consistent with the program's objectives. Academic advising will play an important role in helping students plan their programs. The general degree requirements are the same as for all other WPI baccalaureate degrees, but the distribution requirements of the LES program listed in Table II are different. The

Requirements	Minimum Units
1. Mathematics and Basic Sciences (See Notes 1,2)	3
2. Engineering Science and Design (See Notes 3, 4, 5)	3
3. Social, Humanistic, Business, and Financial Topics (See Notes 6, 7)	3
4. MQP (see Note 8)	1

Notes:

1. Mathematics must include differential and integral calculus and either probability or statistics.
2. All courses with prefixes BB, CH, PH, or GE count toward this requirement. Must include at least 1/3 Unit each of BB, CH, and PH.
3. Courses with prefixes BME, CE, CHE, CS, ECE, and ME are eligible to count toward this requirement. These courses should be thematically related; students must gain approval of their program of study in this area from the LES Program Committee.
4. Must include either CS 1101 or CS 1102.
5. Must include at least one course in engineering design (such as ECE 2799 or ME 2300), plus at least two other courses with a significant laboratory component (a list of such courses will be maintained by the LES Program Committee).
6. Must include 2 Units of Social and Humanistic Topics. Courses with prefixes AR, HI, PY, RH, WR, IMGD, and SS are eligible to count toward this requirement. Courses must be selected from areas that strongly complement the practice of engineering, such as the history of technology, ethics, writing and visual rhetoric, economics, society-technology studies, and environmental studies. A list of such courses will be maintained by the LES Program Committee. No more than 2 courses used to satisfy the Sufficiency Requirement can count toward these Distribution Requirements.
7. May include up to 1 Unit of Business and Financial Topics. All courses with prefixes ACC, BUS, ETR, FIN, MKT, MIS, OIE, and OBC are eligible to count toward this requirement.
8. The MQP provides a capstone experience that builds on both the technical (Engineering Science and Design) and nontechnical (Social, Humanistic, Business, and Financial Topics) components of the student's particular program. At least one advisor to the MQP must be a member of the LES Program Committee.

Table II. Minimum Distribution Requirements for a degree in Liberal and Engineering Studies. The various prefixes are described in detail in the WPI Undergraduate Catalog [7].

Engineering Science and Design component of the major (Distribution Requirement 2) must be approved by the LES Program Committee to ensure that it provides students with a focus in some area of engineering. Guidance and examples will be provided so that

Electrical and Computer Engineering Design	Energy and Environment	Engineering and Pre-Law
Engineering Studies		
ECE 2011 Intro. To Electrical and Computer Engineering ECE 2022 Intro to Digital Circuits and Computer Engineering ECE 2111 Physical Principles of ECE Applications ECE 2311 Continuous-Time Signal and System Analysis ECE 2201 Microelectronic Circuits I ECE 2801 Foundation of Embedded Computer Systems ECE 2112 Electromagnetic Fields ECE 2799 Electrical and Computer Engineering Design (design) CS 1101 Intro. to Program Design	ES 3001 Intro. to Thermodynamics ES 3003 Heat Transfer ES 3004 Fluid Mechanics ES 2501 Intro. to Static Systems ECE 2011 ECE 2111 ECE 3501 ME 2300 Intro. to Engineering Design (design) CS 1101 Intro. to Program Design	ES 1020 Intro. to Engineering ES 1310 Intro. to Computer Aided Design ES 2001 Intro. to Material Science ES 2501 Intro. to Static Systems ES 2502 Stress Analysis ES 2503 Intro. to Dynamic Systems ES 3003 Heat Transfer ME 2300 Introd. to Engineering Design (design) CS 1101 Intro. to Program Design
Liberal Studies		
PY 2714 Ethics in the Professions HI 1332 History of Technology HI 3331 Topics in Society/Technology Studies SS 2208 Society-Technology Debate SS 2302 Science and Technology Policy SS 3278 Technology Assessment/Impact Analysis OIE 2850 Engineering Economics BUS 2950 Business Law and Ethics ETR 3910 Recognizing and Evaluating New Venture Opportunities	PY 2717 Phil.&Environ. SS 2311 Ev. Policy & Law SS 2405 EV Problems & Human Cognition SS 2312 International EV Policy HI 3333 American Tech. Development SS 2302 Science and Technology Policy OIE 2850 Engineering Economics BUS 2950 Business Law & Ethics MIS 3720 Bus. Data Mgt	SS 1303 American Pub. Policy SS 1310 Law, Courts, Politics SS 2313 Intellectual Property Law SS 2314 Cyberlaw and Policy SS 2304 Govt, Decision making and Admin. Law SS 3278 Technology Assessment and Impact Analysis Seminar BUS 2950 Bus Law & Ethics OIE 2850 Eng'g Economics FIN 2250 Financial System of the US

Table III. Three examples of how students might construct an LES program. In addition to the courses listed here for the Engineering and Liberal studies requirements, the student select courses to meet the WPI general education requirement and the Mathematics and Science requirement. For a detailed description of each course, see [7].

students know in advance what types of programs will be approved. The intent is to accommodate creative programs while avoiding programs that lack a coherent theme.

The Social and Humanistic Factors component (see Distribution Requirement 3 and Note 6) should consist of courses that complement engineering and technology to support the educational objectives of the program. The Program Committee will maintain and make available to students and advisors lists of current courses that are acceptable for credit toward this requirement.

The LES degree program is designed to be flexible. However, it must introduce the two cornerstones of engineering, engineering science and design, in a meaningful way, along with a substantive treatment of humanistic, social, and business factors related to

ECE Design with Social, Humanistic, and Business Factors of Design: “Design of a Low-Cost Lighting System Suitable for the Developing World” “Baseline Design and Business Plan for Integrated Household Information Systems” “Social Impact and Economic History of the Microprocessor” Energy with Environment and Policy: “A Brownfields Remediation Plan for Worcester” “Low-cost, Energy Efficient Housing Design” “A Windmill Design to Counter the NIMBY Argument” Engineering Science and Design with Pre-law: “Intellectual Property Issues in Machine Design” “Design and Patent Search for a Better Mousetrap” “The Chainsaw: A Technical, Ethical, and Legal Case Study”

Table IV. Possible senior projects.

engineering and technology. Table III shows three examples of thrust areas that a student might select for a LES degree, along with possible courses used to satisfy the Engineering Science and Design requirement and the Social, Humanistic, Business, and Financial part.

The Senior Project (Major Qualifying Project, or MQP) is an important capstone experience in the WPI curriculum and will remain so in the new program. In the BA program, students have three-unit cornerstones in *both* engineering and liberal studies. At least one MQP advisor must be a member of the LES Program Committee; we recommend that all MQPs be co-advised by faculty teams offering suitable sets of engineering and liberal disciplinary expertise. Table IV lists possible projects that go with the three focus areas listed in Table III.

Students at WPI must also complete a junior project (Interactive Qualifying Project, or IQP) that focuses on the interaction of technology with society. While some of the topics may have some similarity, the MQP is, by definition, in the student’s major, whereas the IQP does not have to draw upon the students’ major for the technological component. This distinction means that for the MQP the student has to build significantly on the base of prior study in two fields they have selected; for the IQP, they must often function effectively in areas new to them. These two project experiences can be different and complementary.

Although the BA in Liberal and Engineering Studies is designed first and foremost for students that intend to pursue a non-engineering career, the program is flexible enough to enable students who wish to become engineers to do so. The first option is to take additional courses and complete a BS in an ABET accredited major. The second option is to pursue a graduate degree in a specific engineering field. A BS degree in an engineering discipline is generally not a requirement for a graduate degree in the same discipline. There is some variability between different programs, but mechanical engineering programs, for example, routinely accept such graduate students from other engineering fields or the sciences. Depending on the students' background, they are, however, often required to take one or more undergraduate courses before matriculating in an MS engineering program. Students from a BA program would be treated in the same way. The MS program would be open to them, but they might be required to take courses in particular areas first.

We emphasize that the "Liberal and Engineering Studies" BA program is distinctively different from a BS degree in engineering in anticipated student market, in curriculum, and in career prospects. In brief, the BS is intended for the student wanting, after four years of study, to begin a career as a design engineer or enter graduate school; the BA is for the student planning a career or further degree in a technologically-dependent field where lesser knowledge of engineering is useful, complemented by a substantial and coherent liberal studies component.

Relation to current trends in engineering education

Although we do not propose to have the LES program accredited by the Accreditation Board of Engineering and Technology (ABET), the program is very much aligned with the vision articulated by the ABET's *Engineering Criteria 2000* (ABET EC2000) [8], which demands transformative change in engineering programs in response to the needs of the profession and the US economy. Under EC 2000, programs are expected to demonstrate that their graduates can communicate effectively, understand the global and social context of engineering problems, understand ethical and professional responsibility, have familiarity with current issues, and have the capacity and inclination to engage in lifelong learning. The EC 2000 vision was echoed in *The Engineer of 2020* [9,10]. Citing rapid global changes in society and technology, the report envisions "engineers who are broadly educated, who see themselves as global citizens, who can be leaders in business and public service, and who are ethically grounded." The document makes a case that corresponding changes must be made in engineering education for the US to maintain economic leadership.

Calling for engineers who exhibit "creativity, ingenuity, professionalism, and leadership," *The Engineer of 2020* [9,10] serves as a reminder that design—solving problems under constraint for the benefit of society—is the signature activity of the engineering profession. To adapt to external pressures, the US engineering workforce must have the innovation, flexibility, and understanding of context that underlie good design practice. ABET EC 2000 [8] also recognizes the importance of design to the profession, requiring a major, integrative design experience considering such factors as ethics, safety, social issues, and political issues—considerations that blur the lines between technical and nontechnical disciplines. However, most engineering teaching and research is done from the relatively "pure" perspective of engineering science rather than the context-driven, problem-oriented perspective of engineering design, allowing much of what students experience in their engineering curriculum to remain unconnected to the liberal learning outcomes of EC 2000. Similarly, engineering students' general education studies are unlikely to be intentionally connected to their professional studies.

What are the characteristics of someone educated broadly in liberal studies and engineering? Certainly, we anticipate significant elements common with engineers educated in one of the disciplines. However, we would also expect to find more breadth of knowledge and abilities in domains outside of engineering and a mature understanding of the relationship between technology and human needs.

First of all, engineers strive to *understand how things work.* Curiosity is certainly a requisite trait. Secondly, engineers can *imagine solutions* to problems. Finally, engineers can *understand interrelationships* of disparate components. Understanding of system behavior as a result of the characteristics of its components is a fundamental engineering ability.

Perhaps the most distinguishing characteristics of the engineer are practical innovation and creative problem solving. These characteristics are embodied in the signature activity of the engineering profession, *engineering design*. Design involves creating solutions in response to stated needs or problems, under a set of constraints that include cost, safety, environmental impact, ergonomics, ethical considerations, sustainability, manufacturability, and reliability. Engineering design is not so much about the latest technology as it is about *appropriate* technology to meet human needs. Students in this program should learn to identify problems, understand user requirements, develop specifications and criteria, evaluate design options, synthesize solutions, bring those solutions to realization, and communicate their results.

Engineers work from a *body of knowledge:* information, facts, laws, and principles. It is important to avoid being prescriptive but, at the same time, important to ensure certain fundamentals. Engineers should be aware, for example, of experimental methodologies that give rise to data. Similarly, they should be aware of the systemization of such data through engineering analysis. Engineers also possess a special manner of thinking about problems – a *mode of thought.* It is analogous to, but different from, the modes used by other professionals such as lawyers, physicians, and businessmen. In a BA program, the engineer's mode of thought is developed through acquiring facility with abstract models of the physical world and relating those models to actual phenomena. Engineers excel at order-of-magnitude analyses, representing the behavior of complex things with simplified models, iteration to home in on solutions, and extrapolation into unknown terrain.

Engineers need to be *literate* in a wide variety of fields. The artifacts of technology have both scientific and social consequences, intended and unintended, and engineers need a broad perspective in order to identify and find appropriate, responsive solutions to problems. Traditionally, physics, chemistry, mathematics, humanities and arts, and the social sciences have formed this basis. However, we should now give serious consideration, on the technical side, to computer science, biology, and information technology; on the humanities, social, and policy sides, students in the program should be familiar with issues in environmental studies, sustainability, ethics, management, culture, esthetics, economics, and written and oral communications. While students graduating from the LES program may lack some of the technical depth ensured by an ABET accredited BS program, we believe that graduates will have acquired the fundamental engineering attributes described above.

Similar Programs at other institutions.

The new LES program at WPI has some similarity with degrees offered at a number of other institutions such as Harvard, Yale, Princeton, and Brown. They all offer ABET-accredited BS degrees in engineering within the context of a traditional liberal arts education. In addition, several institutions offer programs that bear some similarity to what is proposed here. Those include Carnegie Mellon University [11] which has a double major option with an ABET engineering program combined with their "Engineering and Public Policy" major. Cornell University [12] offers an "independent major" where students can design their own engineering program. The Thayer School at Dartmouth College [13] offers a 4 year BA in Engineering with an option for (usually) an additional year to achieve an ABET-accredited BS in engineering. Harvey Mudd College [14] and Smith College [15] offer no disciplinary majors, and the only degree in engineering is a "BS in Engineering." Similarly, Olin College of Engineering [16] offers a major in engineering (in addition to ME or ECE).

Conclusions

Science, technology, and engineering are likely to continue to be the main focus of a WPI education, and the new program does not imply that WPI is departing from its historical commitment to science and engineering. Instead, the new program serves to enlarge the scope of scientific and technologically-based study to better address problems that have significant societal and humanistic dimensions as well as technical. Adopting the BA and this new major are logical extensions of the commitment WPI made in the 1970's to the "New Liberal Arts" (a movement to bring science and engineering into the conventional liberal arts curriculum). A more diverse curriculum will also provide a more intellectually broadening experience for students of all kinds.

Another way to look at the new degree is to view the BA in "Engineering and Liberal Studies"as one promising new path in the ancient tradition of Liberal Education. A BA involving roughly equal study of engineering and the liberal arts responds to many of the recommendations of the recent National Academy of Engineering report; "Educating the Engineer of 2020: Adapting Engineering Education to the New Century", which endorses the vision that "an engineering degree has the potential to become a liberal arts degree for the 21st century" [9]. In addition to arguing for many of the kinds of program changes we propose in "Liberal and Engineering Studies," this NAE report urges that the Master's degree become the first professional degree for the engineering profession. As argued above, both our BS and BA programs could constitute preparation for such a master's degree.

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Author's Biographical Sketches

Patrick Quinn has been the Head of the Humanities and Arts Department and Professor of English Literature at Worcester Polytechnic Institute since 2002. He is the author of *The Great War and the Missing Muse: The Early Poetry of Robert Graves and Siegfried Sassoon* and *The Conning of America: The Great War and American Popular Literature.* He has edited *The Literature of the Great War Reconsidered*, *Re-charting the Thirties, New Perspectives on Robert Graves*, and two volumes of *The Dictionary of Literary Biography Documentary Series* concerning Great War poets. He was the editor of *Gravesiana: The Journal of the Robert Graves Society* and *Focus on Robert Graves and His Contemporaries*. He is the general editor of the twenty-four volume Robert Graves Programme and has edited the *Centenary Selected Poems* and *Some Speculations on Literature, History, and Religion* for the collection. He has published on English, American, Italian and Canadian fiction and poetry, and his Post-Colonial short story anthology of Commonwealth Literature will be published this summer. Quinn was also invited to contribute at a symposium hosted by the National Science Foundation last spring to discuss the place of the Humanities in Science and Technological education.

Lance Schachterle joined WPI as an assistant professor of English in 1970, and has taught a variety of courses and projects in American and British literature. He received his Bachelor of Arts degree from Haverford College in 1966 and his Ph.D. from the University of Pennsylvania in 1970. He has published a variety of studies on Dickens, Cooper, and Pynchon, as well as on liberal and engineering education (receiving the Sterling Olmsted award from the ASEE Liberal Education Division in 1995), and served as the first president of the Society for Literature, Science and the Arts (SLSA). Currently he is Editor-in-Chief of "The Writings of James Fenimore Cooper" (www.wjfc.org), and is working on the first digital edition of a nineteenth-century novel. From 1984 to 1993, he chaired Interdisciplinary Studies and Global Programs at WPI, and contributed to the growth of WPI's Global Perspective Program (through which more than half WPI's engineering majors now have a project experience abroad). In the last several years, he has served as Associate Provost for Academic Affairs, directing ABET and regional assessment activities and overseeing WPI's outcomes assessment programs. His work on creating a BA degree at WPI is based on ideas first expressed in his essay "Liberal Education Responds: Discussing ABET 2000 within a Humanities Division," from the 2004 book *Liberal Education in Twenty-First Century Engineering: Responses to ABET/EC 2000*, part of a series he edits for Peter Lang , "WPI Studies in Science, Technology, and Culture.")

Gretar Tryggvason is a Professor and Head of the Mechanical Engineering Department at the Worcester Polytechnic Institute. He received his doctorate from Brown University in 1985 and spent a year as a postdoctoral researcher at the Courant Institute. After fifteen years as a professor of Mechanical Engineering and Applied Mechanics at the University of Michigan, he moved to WPI in 2000. He has also held short term visiting positions at Caltech, NASA Lewis Engineering Research Center, University of Marseilles, and University of Paris VI. Professor Tryggvason is well known for his research on numerical simulations of multiphase and free-surface flows, vortex flows, and flows with phase changes. He is an active member of several professional societies, a fellow of the American Physical Society and the American Society of Mechanical Engineers, an Associate Editor of the International Journal of Multiphase Flow, and the editor-in-chief of the Journal of Computational Physics. Most recently, he received the 2005 Computational Mechanics Award from the Computational Mechanics Division of the Japan Society of Mechanical Engineers (JSME)

Richard F. Vaz received the PhD degree in electrical engineering from Worcester Polytechnic Institute, focusing on signal analysis, image processing, machine vision, and communication theory. Before entering academia, he held positions with the Raytheon Company, GenRad Inc., and the MITRE Corporation in the areas of systems, satellite, and test engineering. Since 1987, Rick has been on the faculty of WPI, where he is currently Associate Dean of Interdisciplinary and Global Studies and Associate Professor of Electrical and Computer Engineering. His teaching and research interests include service and experiential learning, engineering design and appropriate technology, and internationalizing engineering education. He helps to lead a worldwide network of 20 Project Centers at which over 450 students per year complete degree-required academic projects. He has developed and advised interdisciplinary and technical student projects in Australia, England, Ireland, Italy, Morocco, Namibia, the Netherlands, Puerto Rico, Thailand, and Washington, DC. Rick has published over 20 refereed articles and is co-author of the Prentice-Hall textbook "Information Engineering Inside and Out". He is the recipient of numerous teaching and advising awards, including the WPI Trustees' Awards for Outstanding Teaching and for Outstanding Advising. He is a senior member of the IEEE, a member of ASEE, and since 2004 has served as a Senior Science Fellow of the Association of American Colleges and Universities, in which capacity he works on science and technology education reform nationwide.