Technological Capability: A Multidisciplinary Focus for Undergraduate Engineering Education

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Introduction

Professional interest in the purposes and scope of liberal education for engineering students tracks a long history during this century, going back perhaps as far as the years immediately after the First World War.[1, 2] Humanities and social science faculty at the University of Virginia's School of Engineering and Applied Science (UVA–SEAS) have been active participants in that debate for more than sixty years. One of the most recent foci of interest in liberal education at UVA–SEAS is a cross-disciplinary emphasis on professional development. In earlier papers, we discussed the development and implementation of the UVA–SEAS Professional Development framework.[3, 4, 5] This paper elaborates on one cardinal attribute of that framework–Technological Capability–and its implications for integrating liberal learning and technical engineering education.

Technological Capability

Technological Capability refers to the capacity of engineers to integrate technical expertise, sociocultural analysis, and professional ethics in analyzing and solving real-world engineering problems. It stipulates that graduates should possess the fundamental, historical, and contemporary knowledge of their disciplines, and be able to use it rationally and practically in a variety of professional activities including analysis, design, experiment, and manufacturing. Arguably the first and foremost goal of engineering professional development, Technological Capability also can serve as an integrative focus for multidisciplinary engineering education. While the necessary core of TC is technical expertise and engineering science, by themselves technical expertise and engineering science are not enough. They must be placed into broader contexts of relevant knowledge and practice–society, culture, and ethics–as recognized in both the ABET 2000 Criteria and in the Professional Development framework that we and others at UVA have designed (see below).[4]

A "strong-program" interpretation of the ABET criteria would stress the importance not just of "supplementing" technical coursework with courses in the humanities and social sciences, but rather building more direct, systematic, and coherent links between the technical and nontechnical components of engineering education. Thus, by this interpretation, a strong liberal-arts foundation would be one that offers at least some coursework which explicitly integrates technical, social, and ethical analysis/problem-solving. Ideally, such coursework would also be developed and taught collaboratively (to some degree at least) by technical and nontechnical engineering faculty.

With these convictions in mind, we collaborated in fall semester 1996 by pairing our sections of

Engineering Design and Technical Communication (for first-year students), developing overlapping assignments and creating opportunities for shared educational experiences, including team research projects. The collaboration was organized generally in terms of the Professional Development framework. Projects included: researching and expressing in detail the range of impacts of commercial air transportation on the environment; designing a single piece of equipment or facility and a procedure for an instructor-selected aspect of flight, ground and support operations that would minimize adverse effects while maintaining safety and economic viability in a global setting; and researching and reporting on several international cases studies on technology and human development. All projects were team-based and included written and oral reporting. The project on technology and human development also included a poster presentation. In all of these projects (albeit to varying degrees) students would develop their ability to analyze complex
systemic relationships related to technology-in-society, including appreciation in both theory and practice of the strengths and limitations of technological interventions and their consequences. Our extensive assessment of this teaching collaboration, including favorable student evaluations of its educational contribution to professional development, encouraged us to believe that a high degree of integration between technical and nontechnical coursework in engineering is not only desirable but also quite feasible. [3, 4, 5, 6]

Professional Development Attributes:
The University of Virginia Model

Graduates beginning their careers should have certain qualities:

Technological Capability: Know and be able to practice technology

Leadership/Cultural Competence: Become leaders in a diverse, complex world

Industrial Readiness: Appreciate functions, dynamics and evolution of "industry"; understand the expectations about their roles, contributions and attitudes

Individual/Team Effectiveness: Understand themselves and others; thrive in diverse and ambiguous situations

Ethics/Values/Service Commitment: Be dedicated to the highest professional and human values

Communication Skills: Can inform others and make decisions in diverse contexts

Career Vision: Begun moving in the direction of their life's work

The expectation is that students possessing a significant measure and balance of these characteristics are most likely to become successful professionals. The framework also recognizes that students need a rich variety of experiences and environments to nurture these attributes.

Continuing conversation and reflection has reinforced our conviction that a nontechnical dimension is essential to the very notion of Technological Capability; the "technical" is not synonymous with the "technological," which encompasses a broader "socio-technical" meaning.[7, 8] If so, then perhaps the possibilities for a tighter integration of liberal learning into the technical core of engineering education are even more promising than we had originally assumed. (Let us not forget that the Society for the History of Technology, the leading professional association for historians of technology, was formed in 1958-59 by participants in ASEE's Humanistic-Social Division, now known as the Liberal Education Division.) Perhaps, in short, the gap between liberal learning and technical education is not as wide many engineering educators assume.

There is, in fact, a large body of historical, empirical, and theoretical work in the social study of technology that makes precisely this claim. Major conclusions from this body of scholarly work, which has accumulated over several decades, are that: technology and society are a seamless web; [9, 10] the technical and nontechnical are intertwined dimensions of "technology practice"; [7, 8] and "technological systems" themselves coordinate social and material processes and structures. [11] Such systems–telecommunications, surface and air transportation, industrial manufacturing, marketing and retailing, among others–are characterized by their growing cross-systemic integration and socioeconomic importance. We interact, in our daily lives, with and through increasingly more complex, sophisticated, and integrated technological systems; dramatic improvements in information technologies and their global diffusion are making these systems more significant than ever before.[12]

For example, the convergence of computing, telephony, and television (each of which emerged and developed as separate technological systems) has been spurred on by yet another powerful technological system--the Internet. As these "systems of systems" evolve, they also alter social institutions and social behavior in often unpredictable ways. The appropriate expertise for understanding these huge new systems cuts across several fields of engineering–computer science, civil and mechanical engineering, electrical engineering, and systems engineering, among others–as well as some branches of the social sciences, especially economics, policy analysis, and the social analysis of science and technology. Finally, the dramatic growth of technological systems raises a host of troubling ethical issues related to privacy, safety, equity, and risk.[13, 14, 15]

Conclusion

In conclusion, we are convinced that one promising way to promote greater integration between liberal learning and technical engineering education is through an expansive notion of Technological Capability. Engineering students should cultivate their capacity to think about how technical artifacts and systems interact with cultural values, professional ethics, and socioeconomic development. Few undergraduate engineering curricula today do this well. Most graduates are thus ill-prepared to understand the manifold links between technical-scientific, sociocultural, and ethical dimensions of engineering practice. Integrated, multidisciplinary engineering coursework that emphasizes case-based problem-solving, especially via team-based projects, and (ideally) collaborative teaching, can make these links more evident to students. We conclude that Technological Capability is both a desirable and a practicable focus for nurturing multidisciplinary engineering education and for bridging the gap between liberal learning and technical education.

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