Conceptualizing Integration as Transformation and Point of View

Kathryn Neeley, Melvin Cherno
University of Virginia

I. Introduction

We have designed this paper as an essay in intellectual genealogy. That is, it traces the ancestry of our own thinking about integration. We have selected five authors and intellectual traditions that we have found particularly useful as sources of models and terminology for thinking through the concept of integrating the humanities and social sciences into engineering education.

There are two common threads running through these authors and traditions. First, they conceptualize integration as transformation, in the sense that the process changes the components out of which a new, integrated whole is created. Second, they emphasize the importance of point of view, which recognizes that individuals, groups, and bodies of knowledge typically do not stand in fixed relation to each other, but rather have different relationships depending on the purpose for which they are brought together. None of the authors or traditions provides a solution; all of them provide suggestive ways of grappling with the central challenge of integrated thinking: conceptualizing the complex relationships between parts and wholes.

We believe that the foundation of integration is thinking in terms of engineering practice rather than particular disciplines or curricula. As our examples will demonstrate, there is a long history of thinking about the various forms of knowledge that are essential for successful engineering practice. Although there are many authors and intellectual traditions available, we focus in this paper on two historical examples and three contemporary ones. The two historical examples are the Roman architect Marcus Pollio Vitruvius [1] (1st century B.C.) and the medieval concept of the arts and sciences. The three contemporary examples include Robert Pirsig [2], philosopher and author of *Zen and the Art of Motorcycle Maintenance* (1974); Günter Ropohl [3], a German engineering educator; and Arnold Pacey [4], historian of technology and author of *The Culture of Technology* (1983).

For the two historical examples, the integration of various forms of knowledge is a fact. For the other three, the lack of integration is a problem to be overcome. The remainder of this paper outlines the features of each author or tradition that have been most important for our thinking and indicates how they help define the concept of integration.

II.Vitruvius: Locating and Complementing Expert Knowledge

Marcus Pollio Vitruvius was the author of the *Ten Books on Architecture* [1], the only treatise on architecture and engineering to survive from classical times. To understand Vitruvius, it is important to remember that architecture and engineering were not distinguished from each other during his day (1st century B.C.) and were viewed as part of the integrated activity of building.

He was writing comprehensively about all aspects of building and covered everything from city planning to laying out temples, providing water supplies, and making machines of war. He was not a theorist, but we do know that he had strong opinions about the training of engineers and of the role of building in human culture.

The Training of Engineers/Architects. In the first of his *Ten Books on Architecture*, Vitruvius asserts that "The architect should be equipped with knowledge of many branches of study and varied kinds of learning." (p. 5). The wide range of knowledge he prescribes falls into four basic categories: (1) direct application in the mechanics of design and construction (acoustics, physics, astronomy, drawing, geometry, materials, and arithmetic); (2) making the architect's work intelligible and meaningful to his client and to other members of his culture (communication, cultural history); (3) making his project workable in relation to context and use, including connection to various social systems and customs (geography, religious customs, medicine, law); and (4) making the architect ethical or "high-minded" (philosophy). Throughout the *Ten Books*, he is guided by a concrete vision of the use to which a design or system will be put. He defines the context of engineering broadly, and considers factors ranging from religious and social customs to climate and maintenance.

Commentators on Vitruvius sometimes assume that he is making a highly unrealistic claim about the *expert knowledge* that engineers should possess. But Vitruvius, in fact, makes an important distinction between two forms of knowledge: (1) what is "common to all scholars" and forms "a common ground for discussion" (p. 12), what might be called "*contextual knowledge*" and (2) what one must know for "the doing of the work" (p. 11)/"the actual undertaking of works" (p. 12), which might be thought of as "*technical knowledge*." The contextual knowledge architects must possess is "a knowledge of those parts, with their principles, which are indispensable for architecture." (p. 12) Knowledge of the second kind—for actually undertaking and executing projects—is special to architecture. Vitruvius' analysis thus makes a place for both shared and specialized knowledge within the realm of engineering practice, an approach that is quite compatible with the core competencies identified by ABET 2000

The Act of Building and the Development of Civilization. Although Vitruvius does not make an explicit connection, it seems reasonable to assume that his notions about the knowledge an architect should possess grow out of his view of the origins of building, which he outlines in book two in an account called "The Origin of the Dwelling House." In this account, human beings first came together through the accidental discovery of fire and the subsequent cooperation required to keep the fire burning. This cooperation required the development of language. Then, the combination of social interaction with observation and manual work led to imitation and a cascade of innovations in the intellectual, practical, and social realms. As Vitruvius expresses it,

> Therefore it was the discovery of fire that originally gave rise to the coming together of men, to the deliberative assembly, and to social intercourse. . . .they. . .gradually advanced from the

> construction of buildings to the other arts and sciences, and so passed from a rude and barbarous mode of life to civilization and refinement. (pp. 38 and 40)

Throughout the *Ten Books*, Vitruvius emphasizes two important relationships that are useful in maintaining an integrated view: (1) the connection between the development of building and the development of civilization and (2) the synergistic relationship between the exercise of manual dexterity and the development of intellectual capacity. He talks about the breadth of knowledge required but not about problems of integrating the parts into a whole, perhaps because the various departments of knowledge were not distributed throughout a team but were rather united in a single person who had the opportunity to discern the relationships and interactions among the various "departments of knowledge." The requisite body of knowledge includes all of the essentials for executing any particular act of building plus a comprehensive understanding of the context of building, including the environment, use, and the value attached to a structure or device.

III. Medieval Concept of the Arts and Sciences

Medieval thinkers had a love for classifying and a talent for doing so perceptively. In the process, they often stumbled on genuinely integrative concepts. One major medieval distinction was that between arts and sciences, essentially the distinction between bodies of techniques for accomplishing human purposes and bodies of information about reality. In either case, the general category was an integrative concept, a whole, that not only grouped together a collection of separate parts but also gave each of them an identity, a raison d'etre. There were liberal arts, fine arts, technical arts. Until they were jointly classified into a whole, as arts, they were merely separate phenomena, useful to human beings, but devoid of a conceptual basis. Once it was recognized that they shared a common "art-hood," it was possible to generalize about them and their role in human affairs. One might say that the parts "needed" being made part of this conceptualized whole to achieve cosmic significance, that being given this cosmic significance "transformed" them. The same was true, of course, of the sciences—only when their informational status was substantiated through their being *thought of* as sciences were they capable of revealing God's universe to mankind.

Each of the kinds of art (and of science) was itself an integrative concept, a whole. Surveying and agronomy were technical arts; only when they had been conceptualized as technical arts could their true value be grasped. They "needed" the broader concept to be recognized for what they were; being "placed" in the broader concept "transformed" them. We can, fortunately, take this kind of definitional integration farther than the medieval thinkers did. We can, for example, talk about the ABET 2000 proposals as themselves calling for an integration of this kind, precisely between what the middle ages called the liberal arts and what they called the technical arts. We don't have a name yet for the cover concept, but it should perform the same function we have been talking about—to reveal a new "wholeness" that transforms both the liberal and the technical arts and thus to demonstrate that they "need" each other in order to achieve a higher order of meaning. What we have here is, in fact, a vast hierarchy of wholenesses. A particular liberal or technical project is an integrated whole, a particular liberal or technical art is also one, the liberal arts as a whole are one, as are the technical arts as a whole; finally comes the wholeness that integrates the liberal and the technical arts.

IV. Pirsig: Quality, Parts, and Wholes

For years, Robert Pirsig's *Zen and the art of Motorcycle Maintenance* [2] was a mainstay of instruction in what was then our Humanities Division. Some of us were put off by the book's length (400+ pages) and complexity (simultaneously an account of a summer motorcycle trip, an account of the author's earlier intellectual quest, and a set of lectures, all subsumed under the subtitle of An Enquiry into Values). But it made at least some kind of impression on each of us. It was hard for any of us to come away from the experience of grappling with Pirsig without getting his main point—that Quality (with a capital Q) in any enterprise is a result of combining a romantic (caring) approach with a classical (analytical) one. The narrator eventually reaches a kind of catharsis—becomes "cured," actually—when he comes to realize, on his motorcycle trip with his young son, that he has stripped away the emotional part of his life in favor of an almost unbearable logic-chopping intellectuality. Most of us found the book moving, albeit potentially tedious, and have continued to internalize its integrative lesson, long after we stopped reading the book with our students.

What does Pirsig contribute to the ABET 2000 conversation? A common perception is that many engineers themselves tend to overintellectualize their problem-solving (and perhaps even their lives). That perception is no doubt largely built on a stereotype, but one hears it enough to become suspicious that many engineers could probably benefit from a dose of Pirsig's remedy. A second perception, probably free of any stereotyping, is that most engineers are Quality-seekers, and hence could benefit from Pirsig's elaborate discussion of what Quality is. Certainly our use of his book grew out of our hope that reading it would offer these benefits to our engineering undergraduates.

But we can take the Pirsig lesson further. With only the slightest shift in terminology, we can talk about the ABET 2000 proposals as an effort to create a Quality engineering undergraduate education. And the way to achieve Quality, as in Pirsig, is by integrating the technical (largely classical) with the evaluative and human (largely romantic). An ethical emphasis, a global emphasis, and the other emphases called for by ABET 2000, all would form a higher, transforming whole out of both the classical and the romantic elements of engineering.

V. Ropohl: A Metatechnological Perspective

The German engineering educator Günter Ropohl provides a particularly vivid conception of integration as point of view [3]. Ropohl gives a name to the integrated perspective. He uses the term "metatechnology" to describe this perspective and defines it as "the attempt to understand the complexity of the totality of technological practice." (p. 286) It includes the humanities, philosophy, and the social sciences. He contrasts it with "specialized disciplinary studies in those fields" in three senses: (1) "it begins with concrete technological phenomena;" (2) "it brings in and makes use of nontechnical knowledge, but only as related to technological practice."; and (3) "its use of nontechnical knowledge focuses on specific issues in socio-technical systems." (p. 286)

The metatechnological perspective incorporates the knowledge and perspectives of practitioners as an integral element but does not establish a hierarchy. Indeed, one of the most important features of a metatechnological perspective is its emphasis on the complementarity of various kinds of knowledge. Within this view, an understanding of technology practice may be thought of as a puzzle of many pieces, which originate in different expert communities but which are all necessary for a complete picture. Metatechnology is much more a perspective than a discipline or area of expertise. A metatechnological perspective significantly expands most traditional notions about what is relevant to the engineering enterprise. This expanded view, which is so much a part of current thinking about engineering, was relatively novel in the early 1990s when Ropohl began writing about it.

The problem as Ropohl defines it is that "engineers have so far generally confined themselves to perfecting technical components, neglecting the sociotechnical and ecotechnical relationships of all systems." (p. 281) He argues that "In order to improve engineering education and make it responsive to the demands of society" (p. 285), we need "to cultivate a comprehensive view" and a "unifying perspective." In elaborating his proposal, Ropohl lists "some disciplinary perspectives required for the solution of technology problems." (p. 287) These include human ecology, anthropology, psychology, ethics, aesthetics, economics, sociology, policy studies, political science, legal studies, and history." (p. 287) The challenge, Ropohl argues, is to take "isolated bits of information" and integrate them "within a unified body of knowledge or interpretive system." For Ropohl, integration is a goal to be achieved rather than a fact of life.

VI. Pacey: Technology Practice

Arnold Pacey provides the conceptual basis for the interpretive system Ropohl calls for [4]. In the process, Pacey provides the basis for relating the elements that make up a metatechnological perspective and for locating expert technical knowledge within it. Pacey's approach is more comprehensive than Ropohl's in that it considers not just disciplines but also a wide range of institutions and cultural actors. Like Ropohl, Pacey starts with concrete cases. One of the greatest strengths of the model he provides is that it captures the complexity associated with sets of technology-related practices while at the same time making them manageable for analysis.

Making an analogy to the distinction between medical science and medical practice, Pacey develops the concept of technology practice, which includes three distinct but related elements: the technical, the organizational, and the cultural. This way of looking at technology might be represented graphically as a triangle like the one below.

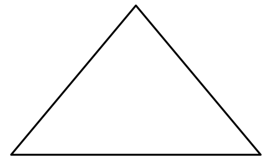

Fig. 1. The Key Elements of Any Set of Technology Related Practices [4]

The technical aspect includes what is often meant by the term "technology" when it is used in a limited and restricted sense: skill, technique, tools, and basic knowledge of the principles of operation of the natural world. The organizational aspect encompasses the various institutions and groups who are involved with generating, controlling, using, or consuming scientific knowledge and technological devices, as well as the infrastructure that makes them an integral part of larger patterns of human activity. The cultural aspect includes values, beliefs, customs, ethics, assumptions, and perceptions, as well as images, symbols, aesthetics, and commonly told stories. In the aggregate, it might be generalized as world view.

Pacey contributes to our understanding of the difficulty of integrated thinking by identifying and exploring the consequences of a subtle but significant shifting of levels of meaning attached to the term technology, which refers to both the strictly technical element *and* to the whole of technology practice, typically without recognizing that there is a difference in scale and scope. This misidentification leads, in turn, to a limited perception of technology, especially with regard to how technology figures into problems and solutions.

Pacey also recognizes that expert communities develop a distinctive culture that limits their perspective. Experts, Pacey argues, tend to focus on the parts of the problem that are of "direct technical interest. . . .They reduce the globe to an 'expert sphere' which they know in detail, leaving a completely different view—a 'user sphere'—which they ignore." (p. 50) This recognition of expert and user spheres is conducive to integrated thinking. It accounts for differences between expert and non-expert points of view by showing how they both overlap and are distinct. It also recognizes that the categories of expert and non-expert are not permanent but rather shifting.

VI. Conclusion

Having spent a great deal of time thinking about these issues, we were quite surprised when we realized that the term "integration" actually does not appear in the ABET 2000 accreditation guidelines. We believe that the models for thinking about integration that we have presented here reflect a philosophy that is remarkably similar to the one underlying ABET 2000, but we also realize that the integrative foundation of the new criteria needs to be clearly articulated if people are to act on it in a meaningful way. At a minimum, we believe that a curriculum that meets the demands of ABET 2000 will transform the traditional disciplines that are included within it and be permeated by a point of view that encompasses systems as well as components.

The need for and obstacles to integration are perhaps more obvious to those of us in the humanities and social sciences, but they exist throughout the engineering curriculum. Drawing on the terminology we used in describing the outlook of the Middle Ages, we might conclude that engineering has not yet discovered its "art-hood," or sense of intellectual and cultural identity, and that one of the greatest promises of ABET 2000 is the incentive it provides for engaging the whole range of human knowledge and experience in that effort.

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KATHRYN NEELEY
Kathryn Neeley is an Associate Professor of Technology, Culture, and Communication in the School of Engineering and Applied Science at the University of Virginia. She received a Ph.D. in English in 1989 and teaches interdisciplinary courses for engineering students that combine professional communication, engineering ethics, and the cultural history of science and technology. She is also an active member of the Humanities and Technology Association.

MELVIN CHERNO
Melvin Cherno is the Joseph L. Vaughan Professor of Technology, Culture, and Communication in the School of Engineering and Applied Science at the University of Virginia, where he has served since 1980. He is interested in public awareness of technological developments and participated in the project on HSS instruction in undergraduate engineering education that led to the publication of the report *Unfinished Design: The Humanities and Social Sciences in Undergraduate Engineering Education* (ed. Johnson, Sharman, and Zemsky, 1988).