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Knowledge Integration as the Foundation of Ethical Action: or, Why You Need All Three Legs of a Three-Legged Stool

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Ethics coursework typically aims to enhance students' ability to discern moral issues and evaluate alternatives in order to make decisions. These are important outcomes. However. . .*a moral judgment has no value unless it leads to a moral act*.

--Comer and Schwartz, "Highlighting Moral Courage in the Business Ethics Course," 2017, p. 703

The concept of "ethics in action" expresses the conviction that the ultimate goals of engineering ethics education are achieved in contexts other than college classrooms and make multiple demands on individual engineers. By extension, ethics in action necessitates taking the contexts of action into account in instructional design. From the perspective of assessment, "ethics in action" is problematic for instructors who encounter students only in the classroom context. It is nonetheless quite useful because it provides an integrative, non-hierarchical framework that allows us to think about engineering ethics education on a larger scale than we ordinarily do. It also opens up the possibility of recognizing the structural factors that have made it difficult to integrate ethics into the engineering curriculum on a systematic basis.

Despite an abundance of resources available to support engineering ethics instruction, including cases provided through the Online Ethics Center (OEC), "the engineering literature is devoid of research that definitively identifies the most effective pedagogical method for introducing students to engineering ethics" [4, p. 677]. Perhaps most tellingly, the only clear qualification for teaching engineering ethics is being "enthusiastic about and comfortable with discussing ethical issues and the social implications of engineering" [4, p. 680]. Barry and Herkert express this lack of clarity when they conclude that "although a background and experience in philosophy and engineering might make an individual well prepared to teach engineering ethics, a well-prepared instructor from history of science or technology, technical communications, science and technology studies, and so forth could be equally qualified" [4, p. 680]. This flexibility opens up the possibility of increasing the number of faculty qualified to teach engineering ethics but also creates ambiguity about the knowledge base on which engineering ethics relies. One possible explanation for the lack of clarity is that engineering ethics is fundamentally interdisciplinary, which means that no particular area of disciplinary expertise is uniquely relevant.

In their discussion of "Interdisciplinarity in Ethics," Mitcham and Wang argue that "Ethics is inherently interdisciplinary, yet not always pursued as such" [21, p. 241]. Its strongest disciplinary association is with philosophy, but "Especially in its contemporary applied or practical versions, ethics is a hybrid of disciplinary concerns in, for example biomedical ethics, environmental ethics, and computer ethics—each of which depends on multi- and cross-disciplinary interactions" [pp. 241-242]. As an inherently interdisciplinary field, engineering ethics sits uneasily in the disciplinary structures that dominate higher education. While there is no shortage of valid criticisms of disciplinary thinking (some of which will be discussed later in this paper), those structures are resistant to change, and waiting for large-scale structural change is incompatible with the sense of urgency surrounding engineering ethics.

This paper presents a conceptual model of how three knowledge streams—engineering ethics, communication, and sociotechnical systems thinking—come together in engineering practice and can be integrated simultaneously into engineering curricula. The three streams are defined below.

1. Engineering ethics: cultivating a practical and actionable understanding of professional and ethical responsibility in engineering students and practitioners
2. Engineering communication: developing communication proficiency in engineering students and practitioners
3. Sociotechnical systems thinking: taking a holistic approach that locates engineering expertise and projects in human activity in specific settings

The central metaphor around which the model is constructed is the three-legged stool, which maintains its stability in challenging situations but loses functionality if any one of the legs is missing or deficient.

The Problem: Underutilized Intellectual Resources

Over the last twenty-five years, several mutually supportive trends have fueled growth in engineering ethics. Analysis of disasters and cases is now complemented by ethically motivated approaches to engineering design [4]. Recognition of the symbiotic relationship between micro-ethics and macro-ethics has illuminated the connection between ethics and the social implications of technology [11]. Communication in its many manifestations is increasingly recognized as a fundamental aspect of engineering practice, as evidenced by the pervasive interest in communication across the many divisions of the American Society for Engineering Education [22]. During that same period, awareness of the ethical implications of technology has diffused through engineering professional societies and become more prominent in public discourse [20]. It appears, then, that engineering educators have ample resources for integrating ethics into engineering curricula.

All of this progress notwithstanding, there is no established strategy for putting these resources to work in a systematic way. In their "Systematic Literature Review of Engineering Ethics Interventions," Hess and Fore astutely observe that "Ethical *potential* [emphasis added] is . . .present within every event," so it is in theory possible for ethics to "be seamlessly integrated while students practice and perfect their technical knowledge and skills" [12, p. 574]. That said, the omnipresence of ethical potential in engineering practice does not automatically translate into easy integration of ethics into engineering education. The same can be said for communication and sociotechnical systems thinking, both of which are integral to engineering practice but difficult to integrate into the engineering curriculum.

One of the most significant undertainties in the field is the lack of clarity regarding how much ethical content should be included [4]. While some degree programs and institutions invest significantly in engineering ethics, the ABET requirement for ethics can be satisfied with a one-hour lecture in a senior design course. Additionally, despite the existence of several different approaches to integration, ranging from stand-alone required courses to micro-insertions in technical courses, no standard method of integration has been established. Required stand-alone courses seem impractical based on the investments of money and curricular space that they require and can imply that ethics is outside of engineering. Micro-insertions have the potential to infuse ethics throughout the curriculum but are more often embedded than integrated into technical courses. In other words, the ethics content comes across as forced into a surrounding mass rather than amalgamated holistically. And this seems to be the case even when both faculty and students are positively disposed toward engineering ethics content [18].

Beliefs and assumptions about disciplinary coherence and autonomy (or lack thereof) shape our thinking and are not usually the subject of critical reflection. The analysis presented here draws on the literature on interdisciplinarity to engage in such critical reflection. The intent is not to denigrate or devalue disciplinary expertise, but rather to understand the ways that disciplinary thinking and structures limit the possibilities for bringing academic expertise to bear in contexts that are not organized by disciplinary structures.

How Research on Interdisciplinarity Clarifies Its Purposes and Challenges

Robert Frodeman provides an approach that is particularly useful in the context of engineering ethics because it focuses on the reasons why people seek to bring together multiple forms of expertise: “Interdisciplinarity is most commonly used as a portmanteau word for all more-than-disciplinary approaches to knowledge, with the overall implication of *increased societal relevance*” [emphasis added] [9, p. 5]. Frodeman’s conception of interdisciplinarity resembles “convergence,” an approach promoted by the National Science Foundation in which research and teaching focus not on disciplines, but rather, on areas where disciplines converge, typically complex and compelling “real-world problems and challenges that require initiative and creativity” [14, p. 7] The impetus towards relevance is often squelched by “disciplinary capture,” a process in which “the need for epistemic bona fides within one’s own reference community” overwhelms the desire to establish relevance outside of it [9, p.5]. Disciplinary capture is but one manifestation of the pathology of discipline-centric thinking. Used in a metaphorical sense to describe a problematic way of thinking, being pathological means treating disciplinary structures as both all-powerful and inevitable. Research on various aspects of interdisciplinarity has identified some specific manifestations of this pathology, which are discussed below.

It seems reasonable to view engineering ethics as an effort to make academic ethics relevant to transdisciplinary public concerns. Those concerns arose in the 1970s in the wake of “a series of engineering-related disasters (most prominently involving automobiles and airplanes)” and in the 1980s from “fraud and misconduct in science, including the use of public funds” [21, p. 251]. These public concerns led to public funding of “transdisciplinary collaborations between technical professionals and philosophers” [p. 252]. Like Frodeman [9], Mitcham and Wang acknowledge that within academia, “the *practice* of interdisciplinarity often remains transgressive. . . .Philosophers who specialize in applied ethics are not always accepted as equal members of their departments [which raises] questions about the professional and cultural boundaries of applied ethics work” [p. 253]. In other words, a focus on ethics as *practice* threatens the status of engineering ethics as a scholarly discipline while simultaneously increasing its social relevance.

Karri Holley explains why departmental structures are perhaps the most durable obstacles to interdisciplinary in her chapter on administering interdisciplinary programs in *The Oxford Handbook of Interdisciplinarity* [13]. First, there are the territorial disciplinary groupings that have a physical footprint in campus buildings and in documents such as academic catalogs that distribute "topics of study and fields of knowledge among. . .colleges and departments" [p. 531]. Second, academic units tend to be in loosely coupled forms of organization in which "units do not rely on other units to survive [and] the motivation for shared and collaborative behavior declines" [p. 532]. Third, a professional bureaucracy privileges assessments of disciplinary peers outside of a faculty member's home institution. The combination of these features means that "Shared space that allows collaboration" has to be created, usually by "some institutional authority outside of the typical departmental unit" [p. 533]. If that authority changes hands or changes its priorities, the shared space may be eliminated. Finally, there is a lack of standard forms for organizing interdisciplinary enterprises, both in the sense of finding a home within the administrative structure of the institution and providing "an integrative foundation" [p. 537].

The inertia created by disciplinary structures is exacerbated in engineering because of the hyper-territorial character of ABET accreditation. Unlike other accrediting bodies such as the Southern Association of Colleges and Schools (SACS), ABET accredits degree programs rather than institutions. Within schools and colleges of engineering, departments see protecting their knowledge domains as an existential imperative. If a single degree program is not accredited, the status of other degree programs in the same institution is not threatened. Thus, the departments have no significant stake in the welfare of other departments and thus no incentive to seek common ground.

All interdisciplinary enterprises must overcome the tendency to treat expert and non-expert as exclusive categories rather than ends of a continuum. Regardless of our fields of specialization, all of us are non-experts in some spheres. Recognizing different degrees of expertise can support what Gabriele Bammer [3] describes as an "integrative applied" approach, which "involves experts from various disciplines and stakeholders from relevant practice areas working on a common complex problem, such as cybercrime, obesity or soil erosion, a process that develops not only improved understanding but also supports action on the problem" [p. 525]. She identifies three different levels of expertise that contribute in different ways: (1) a small core who develop the theoretical basis for the discipline, (2) a significantly larger group who use disciplinary theory and methods to engage with real-world problems and generate insights about those problems, and (3) an even larger group who appreciate what the discipline can offer, can apply methods in limited circumstances, and know when more expertise is needed [p. 528].

This recognition stands in contrast to the standard model for conceptualizing the relationship between expertise and power in an academic context: autonomy versus servitude. Faculty operating in this mental model tend to assume that individuals and academic units exist in one state or the other. Either we are teaching students majoring in our fields and have complete autonomy, or we are teaching students in other degree programs in courses pejoratively referred to as "service courses," in which we have lost our autonomy and become subservient. The distinction is also expressed as teaching our expertise in its "fundamental" form rather than its "applied" form. It often seems, then, that we must choose between maintaining status inside and establishing relevance outside of our own fields in academia. This false dichotomy is particularly problematic if effective ethical action outside of academic contexts is the ultimate goal of ethics instruction.

The standalone disciplinary course as the fundamental, interchangeable unit of instruction is another conceptual obstacle. Given the number of ABET outcomes that draw on expertise from the humanities and social sciences, one disciplinary course per outcome is clearly impractical. This kind of compartmentalized thinking tends to overlook the reality that engineering is fundamentally integrative. Recognizing the inherently integrative nature of engineering highlights the reality that integrating different forms of knowledge makes it possible for that knowledge to become relevant in the context of public concerns.

Three Compatible Conceptual Frameworks That Constitute an Integrative Approach

An integrative approach takes advantage of synergies that are obscured by discipline-centric thinking. It shifts the focus from seeking the "missing pieces" of the engineering curriculum to understanding how we can connect existing knowledge streams in a functioning whole. Knowledge integration requires more than recognizing the distorting effects of discipline-centric thinking. It also requires identifying and applying conceptual frameworks that support integration. The integrative approach presented here consists of three compatible conceptual frameworks: (1) the metaphor of the three-legged stool, (2) Arnold Pacey's model of sociotechnical systems, and (3) Martin and Schinzinger's concept of engineering as social experimentation.

The Metaphor of the Three-Legged Stool

The metaphor of the three-legged stool provides us with a way of getting beyond the polar choices of autonomy and servitude and helps us think in a more egalitarian way about the possibilities of integrating different forms of expertise to achieve relevance outside of academia. For our purposes here, the stool is ethical action in the context of human activity in which engineers and technology play an important role.

This metaphor is much used and, as far as I have been able to determine, seldom analyzed in depth. A search of items in my institution's library reveals its use in strikingly varied contexts, including: voter engagement; dentistry; spirituality in the treatment of substance use disorders; protocols governing the use of laboratory animals; the transition from graduate student to tenure track faculty member; sustainable development; the triangular relationship of Britain, China, and Hong Kong; and interactive systems installed in the Museum of Modern Art in New York City. This eclectic range of use cases attests to the flexibility and generative power of the metaphor as well as its intuitive appeal, but it also reflects ambiguity and vagueness. To use the metaphor more precisely requires looking beneath its surface to discern the implications of the mental model it embodies.

The most well-known use of the metaphor is in the context of Social Security benefits, which are designed “to be only one part of a complete approach to retirement planning” [7].The historian’s office of the Social Security Administration (1996) traces the history of the metaphor to Reinhard Hohaus, an actuary for the Metropolitan Life Insurance Company and “an important private-sector authority on Social Security.” In a speech given in 1949, Hohaus captured what appears to be the essence of the concept:

> Each [element] has its own function to perform and need not, and should not, be competitive with the others. When soundly conceived, each. . .can perform its role better because of the other two classes. Properly integrated, they may be looked upon as a three-legged stool affording solid and well-rounded protection for the citizen.

Three implications emerge in this use of the metaphor. First, it helps relevant stakeholders imagine a large, complex system that is not easily compared to existing systems. Second, the constituent parts are neither in competition with each other nor organized as a hierarchy. Third, and perhaps most importantly, the parts are synergistic, that is, their combined output is greater than the sum of their constituent parts. If we were to reword the concluding sentence of the statement above for engineering ethics, the “affordance” (the possibility that the system supports) is a solid and well-rounded preparation for ethical behavior in the workplace. The emphasis on balance contrasts with traditional discourse on education, which treats the school as the primary locus of activity. In the case of engineering ethics, this articulation of the model highlights the extent to which the efficacy of the system depends on equal treatment of each of the three dimensions (engineering ethics, engineering communication, and sociotechnical systems thinking).

A less common but equally relevant use of the metaphor in education occurs in “Stories of the Three-Legged Stool” [8], where Franks, Durran, and Burn use the metaphor to understand drama, media, and English as a joint enterprise—but not with the aim of subsuming the other two under the “imperial title” of English or other umbrella categories such as cultural studies, media studies, and communication [p. 65]. Rather, their aim is “to rethink” each of the legs, “how they connect as well as separate; and, how they might achieve *equal status in combination* [emphasis added]” [p. 66]. This last qualification is particularly important because, as Jasanoff notes in her discussion of science and technology studies and interdisciplinarity, approaches that appear interdisciplinary (that is, an attempt to bring disciplines into productive conversation with each other) are in reality "imperial" because they are attempting to subsume and displace other disciplines [16].

The integrative model developed in this paper is *not* an attempt to subsume engineering ethics, engineering communication, and sociotechnical systems thinking under a newly created discipline or interdisciplinary area—or to locate engineering communication and sociotechnical systems thinking as constituent parts of engineering ethics as a field of specialization. Rather, it is an attempt to introduce what Franks, Durran, and Burn call productive confusion, that is, confusion that calls into question the relevance of disciplinary boundaries for domains of practice outside of academic contexts.

Pacey's Model of Sociotechnical Systems

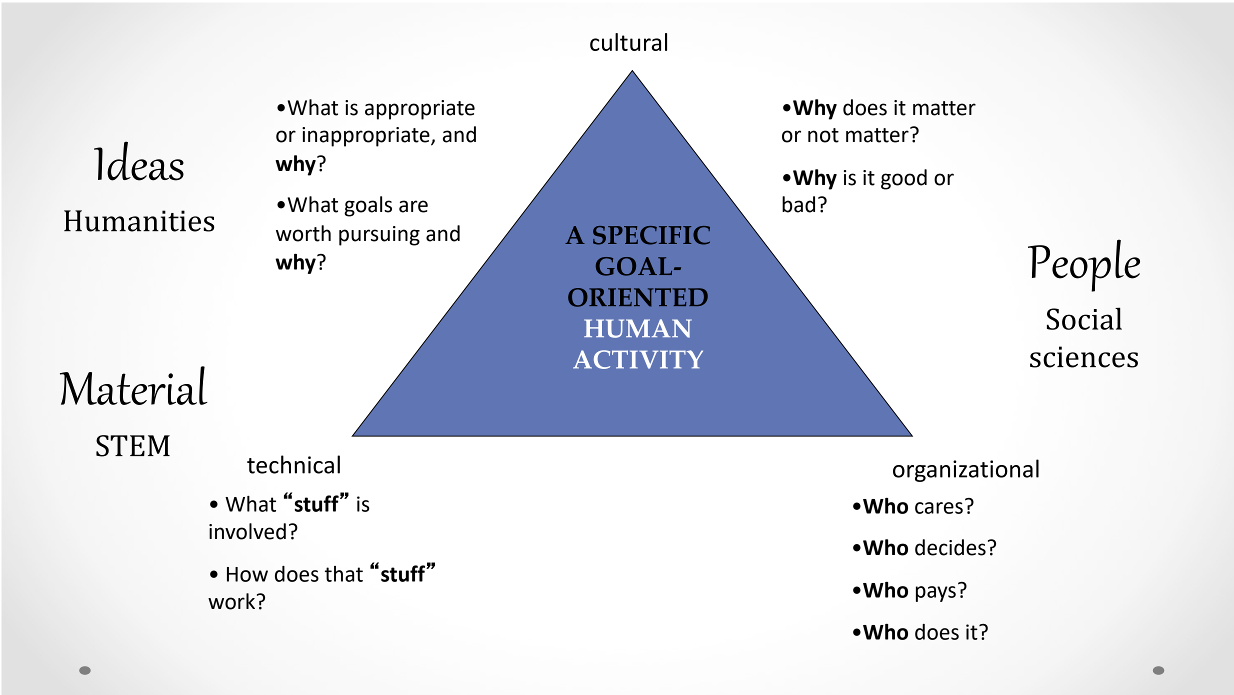
Pacey's model of sociotechnical systems supports knowledge integration in three distinct but related ways. First, it locates technical expertise in the broader organizational and cultural contexts that give it ethical significance. Second, it allows experts from all disciplines to conceptualize how different knowledge streams come together to form the competencies that are essential for ethical action. Third, it helps experts in one domain formulate intelligent questions for experts in other fields.

The fundamental insight underlying sociotechnical systems thinking is that technical artifacts and capability are developed and implemented in a social context. Successful implementation of artifacts and capability entails changes in patterns of human activity, often on a large scale and without the consent of stakeholders who stand to be most affected. The products of engineering take on ethical significance, then, in a social context that is often quite distanced both psychologically and physically from the settings in which engineers design devices and processes. Social construction of technology provides a framework for thinking about the contingent processes by which artifacts are shaped by and in turn shape human choices and behavior.

In *The Culture of Technology* (1987), Arnold Pacey [27] presents a conceptual framework that can serve as a heuristic (if not a method) for understanding sociotechnical systems. Making an analogy to the distinction between medical science and medical practice, Pacey proposes a framework for thinking about technology practice that consists of three highly interrelated but distinguishable aspects: technical, organizational, and cultural. My interpretation of the model for engineering practice appears below.

The technical dimension includes material things and how they work. Some examples of entities in the technical domain are "knowledge, skill and technique; tools, machines, chemicals, liveware; resources, products and wastes" [p. 6]. From a disciplinary perspective, the technical domain is most strongly associated with STEM fields, so this is the domain with which engineers are most familiar. In the most basic sense, the technical domain raises questions about what things are involved and how those things work.

The organizational domain is the domain of people, both individuals and groups. Some examples of entities in the organizational domain are "economic and industrial activity, professional activity, users and consumers, and trade unions" [p. 6]. From a disciplinary perspective, it is most closely associated with the social sciences. The relevant questions in the organizational domain are "who" questions. Who does it? Who funds it? Who regulates it? Who makes decisions about it? Who cares about it? This tends to be the domain that most engineers and engineering students are least knowledgeable about.



The cultural domain consists of ideas and includes goals, values, assumptions, beliefs, and norms. It raises "why" questions. Why is something good or bad? Why does it matter? What goals are worth pursuing and why? Why is something appropriate or inappropriate? As members and carriers of cultures, engineers are familiar with these ideas but may not have articulated or thought about them critically. From a disciplinary perspective, the cultural domain is most closely associated with the humanities.

Pacey's model allows us to see a sociotechnical system as an assemblage of actors—tangible and intangible, human and non-human—that work together synergistically in goal-oriented human activity. One of its most useful features is that it separates what is usually referred to as "social" into organizational and cultural domains, a distinction that is important because the interventions we might make in the organizational domain are very different from those in the cultural domain. Because of the degree of coordination required, sociotechnical systems are hard to establish and manage. Once established they can be very difficult to change.

Analysis using the categories of technical, organizational, and cultural (TOC) can provide insights about interactions and relationships that are relevant to ethics but often go unrecognized. Two commonly discussed ethics cases, the explosion of the space shuttle *Challenger* and the failure of the flood control system in New Orleans during Hurricane Katrina, illustrate the kinds of insights that TOC analysis can generate. Those cases are discussed below in a simplified form. In both cases, the analysis reveals failure as an emergent property of the system rather than the result of the actions of individuals who can be "blamed" for the outcome.

In the *Challenger* scenario, the goal-oriented human activity is transporting human beings into orbit and bringing them back safely. The O-rings in the booster rocket and the freezing temperatures at the time of launch are some of the most significant technical factors. In the organizational domain, the human actors' behavior is shaped by conventions such requiring engineers to provide data demonstrating that it will be safe to launch (vs. proving that it will not be safe) and allowing managers to make commitments to technical specifications that engineers realize they cannot meet. In the cultural domain, two significant actors are (1) the belief that public embarassment caused by failure to launch on schedule is an existential threat and (2) the assumption that the priorities of management matter more than those of engineers, as in the admonition to take off one's engineering hat and put on a management hat.

In the case of the Katrina, the goal-oriented activity is protecting the city of New Orleans from flooding caused by hurricanes. The levees and floodwalls are important aspects of the technical domain because a single point of failure can lead to catastrophic failure of the system as a whole. The location of New Orleans below sea level and between two large bodies of water makes the city very vulnerable to flooding. In the organizational domain, there are many different organizations that make decisions about and maintain the system, and there is no coordinating center or mechanism, a situation that is particularly problematic given the lack of redundancy in the technical domain. In the cultural domain, the tendency to prioritize short term considerations (such as taxpayer reluctance to pay for maintenance) over making the investments necessary to ensure public safety is a significant factor.

Martin and Schinzinger's Model of Engineering as Social Experimentation

The conceptual framework of engineering as social experimentation illuminates the competencies individuals need to act effectively in complex organizational settings, demonstrates how the behaviors that constitute responsible experimentation come together in practice, and makes it easier to link those behaviors to different forms of expert knowledge.

Mike Martin and Roland Schinzinger's *Ethics in Engineering* [19], originally published in 1983, is the result of one of the philosopher-engineer collaborations funded jointly by the National Endowment for the Humanities (NEH) and the National Science Foundation (NSF). Now in its fifth edition, it is one of the two most popular engineering ethics textbooks, reflects what appears to be a seamless integration of ethics and engineering, and demonstrates the combination of creativity and utility that can result from a truly interdisciplinary collaboration. It is particularly suitable for our purposes here because it is organized around the integrative framework of "engineering as social experimentation" (ESE) in which engineering is conceived of as "an experiment on a social scale involving human subjects" [p. 64]

The ESE framework locates engineering expertise and the products of engineers' work in the contexts of implementation, where outcomes are uncertain and largely out of the purview, much less the control, of the engineers who develop technical capability. The framework is developed in detail in the book, but the four basic actions it entails are: (1) recognize uncertainty and contingency, (2) creatively perceive risks inherent in the implementation and use of technical capability, (3) take responsibility—in conjunction with other actors—for avoiding harm, and (4) monitor the outcomes of implementation. In the ESE framework, the experiment begins when engineering projects (as conventionally understood) end. The approach is grounded in virtue ethics, specifically the virtues required of engineers as responsible experimenters:

conscientiousness, including actively seeking out relevant information; moral autonomy; and accountability.

Although the terminology of sociotechnical systems is not used explicitly, ESE is inherently sociotechnical and captures the multiple ways communication (broadly conceived) is part of engineering ethics. The book contains many lists of personal qualities and competencies required for responsible social experimentation in engineering. These are not organized into a clear or consistent taxonomy (set of categories), and there is lots of overlap but no obvious alignment in their content. They do, however, provide lots of substance that could be used eventually to formulate outcomes. The two lists below are presented separately but are informed by the same mindset. The competencies and sensibilities are articulated at a high level as four distinct but related actions.

Competencies and Sensibilities That Foster Moral Autonomy

1. discern and clarify moral problems
2. work out reasoned and sometimes creative responses to moral problems
3. take opposing viewpoints into account
4. exercise the verbal and communicative skills relevant to discussing one's views with others [p. 23]

The practical skills are articulated with greater specificity and thus are easier to translate into educational outcomes to which multiple forms of expertise can contribute.

Practical Skills That Support Effective Independent Thought

1. Recognize moral problems and issues, distinguish them from and relate them to legal, religious, and economics issues
2. Comprehend, clarify, and critically assess various perspectives
3. Form consistent, comprehensive, and evidence-based viewpoints
4. Imagine alternative responses to issues and problems
5. Recognize subtleties and difficulties and tolerate uncertainty
6. Use ethical language precisely to express and defend one's view adequately to others
7. Use rational dialog to resolve conflicts, appreciate and tolerate differences in perspective
8. Integrate one's professional life and personal convictions [pp. 16-17]

The table below summarizes the two lists in the form of actions to be taken and attempts to align the lists with each other. Although the three knowledge streams are combined most of the time, it is easy to see differences in emphasis. For example, the first row primarily deals with engineering ethics but also implies a systems perspective when it mentions "legal, religious, and economic issues." Similarly, recognizing subtleties and difficulties may be primarily a matter of ethical awareness and sensitivity, but the use of language to articulate these subtleties and difficulties and help others understand them clearly entails communication. The second row exhibits similar interrelationships.

Competencies and Sensibilities That Foster Moral Autonomy	Practical Skills That Support Effective Independent Thought About Moral Issues
1. discern and clarify moral problems	1. recognize moral problems and issues, distinguish them from a relate them to legal, religious, and economic issues 5. recognize subtleties and difficulties and tolerate uncertainty
2. work out reasoned and sometimes creative responses to moral problems	3. form consistent, comprehensive, and evidence-based viewpoints 4. imagine alternative responses to issues and problems and develop creative, practical solutions
3. take opposing viewpoints into account	2. comprehend, clarify, and critically assess various perspectives 7b. appreciate and tolerate differences in perspective
4. exercise the verbal and communicative skills relevant to discussing one's views with others	6. use ethical language precisely to express and defend one's view adequately to others 7a. use rational dialog to resolve conflicts
8. integrate one's professional life and personal convictions	

The third and fourth rows place greater emphasis on communication but also include dimensions of ethical awareness and sociotechnical systems thinking. In sum, the inventory of abilities required for ethically responsible behavior in engineering shows how intimately the three knowledge streams are combined in ethically responsible engineering practice.

In a classroom analysis of an ethics case, this inventory could be used to gather and analyze relevant information. For example, the admonition to take opposing viewpoints into account implies the concrete action of identifying different stakeholders and gathering information about their viewpoints. Similarly, concepts drawn from ethical theory could be used to comprehend, clarify, and critically assess various perspectives. Instructors of courses that primarily focus on communication or sociotechnical systems thinking could use this inventory to link their primary subject matter to engineering ethics. These examples only hint at the possible applications of ESE in classrooms and curricular designs.

Conclusion

In sum, this paper argues that it is neither necessary nor desirable to separate the three knowledge domains (engineering ethics, communication, and sociotechnical systems thinking) for the simple reason that they are very much connected in engineering practice. Effectively integrating the three requires reconceptualizing all three areas as both interdisciplinary enterprises and areas of specialization. For the purposes of engineering education, they are not disciplines or courses but rather intersectional knowledge domains that come together for the specific purpose of enabling ethical action on the part of engineers. The first two are explicitly stated as accreditation outcomes in the EC2000 criteria. The third is strongly implied by the outcome "broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context." The mutually reinforcing relationship of the three is apparent in the concept of engineering as social experimentation.

The metaphor of the three-legged stool facilitates knowledge integration because it focuses on overall function and emphasizes the interdependence of component parts in achieving that function. Along with the TOC model of sociotechnical systems and the concept of engineering as social experimentation, it provides a conceptual framework for imagining how we can provide well-rounded preparation for ethical behavior in the workplace by drawing on various forms of disciplinary knowledge. An obstacle beyond those already mentioned is the lack of alignment between faculty expertise and the requirements of curricular designs that prepare students for effective ethical action. An integrative approach to this challenge will *not* create new PhD programs. Instead, it will support educators in locating their expertise within the larger system of engineering education and focus their attention on a shared goal that can resolve apparent conflicts. Most faculty who teach and research engineering ethics began with a monodisciplinary background, branched out into other areas, and have found that expansion gratifying. We are well-positioned to help others do the same.

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