Chapter 13
The Missing Basics and Other Philosophical Reflections for the Transformation of Engineering Education

David E. Goldberg

David E. Goldberg is Jerry S. Dobrovolny Distinguished Professor, University of Illinois at Urbana-Champaign; Co-Director, Illinois Foundry for Innovation in Engineering Education; and Director, Illinois Genetic Algorithms Laboratory, Urbana, Illinois, USA

Introduction

Once again, reform of engineering education is in the air. In the United States, the National Academy of Engineering has published two reports, one specifying characteristics of the engineer of our times (National Academy of Engineering, 2004) and one calling for changes in the ways young engineers are educated (National Academy of Engineering, 2005). A report sponsored by the Carnegie Foundation for the Advancement of Teaching (Sheppard et al., 2008) calls for overhauling the design of engineering education, a national engineering leader has independently called for significant reform (Duderstadt, 2008), and the editor of this volume and his colleagues have called for the education of a more holistic engineer (Grasso and Martinelli 2007, Grasso et al., 2008). The Olin Foundation has gone so far as to have given $460 million dollars to establish a pioneering new curriculum and entirely new school at Franklin W. Olin College of Engineering (Chronicle of Higher Education, 2008) that has now had three graduating classes of seniors. These efforts follow significant funding of eight Engineering Education Coalitions by the National Science Foundation, but a recent report laments the lack of diffusion of those efforts (Spalter-Roth Goldberg et al., 2007).

Although much money, time, and effort has been expended toward engineering curriculum reform, and some successful reform has been achieved, the problems remain daunting, partially because they are complex, surrounded by a lack of

D.E. Goldberg (✉)
Illinois Foundry for Innovation in Engineering Education (iFoundry), University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA
e-mail: deg@illinois.edu

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conceptual clarity, a general confusion about the nature of the engineering enterprise. Two papers elsewhere (Goldberg et al., 2008a, b) have suggested that a primary and underappreciated obstacle to educational transformation is *organizational resistance,* and those papers recommended the formation of a collaborative, interdepartmental curriculum incubator, describing such efforts at the University of Illinois. This chapter asserts that a number of the problems thwarting effective reform are a kind of *conceptual resistance* and are essentially philosophical in nature. The purpose of this chapter is to approach the problem philosophically, reflecting first on what engineering students do not do very well on their first real engineering engagement, continuing by trying to understand some of the conceptual obstacles to aligning engineering as taught with engineering as practiced, and concluding by examining the roles of philosophical analysis in the transformation of engineering education more generally.

Cold War Curriculum Meets Senior Design

The "standard" engineering curriculum of our time was largely set in the aftermath of World War II during the opening days of the cold war period of the 1950s. In the United States, the Grinter report (Grayson, 1993) called for an increase in science, math, and engineering science, and a diminution of shop subjects and graphics. These changes held sway until the 1960s when a number of educators were concerned about a return to engineering design practice in the curriculum (Dobrovolny, 1996). Capstone senior engineering courses trace their beginnings to those discussions, and one of the early leaders in this movement was the Department of General Engineering at the University of Illinois. A Ford Foundation grant in 1966 led to the establishment of an industrial-oriented senior design program, and when the money from that grant ran out, the program was continued using contributions from industry sponsors.

Today, senior design in General Engineering at Illinois continues with successful outcomes for companies and students alike. Currently, teams of three students work with a faculty advisor for an industrial sponsor on a project of practical importance to the company. Additional details about the course are available on the course website (Industrial and Enterprise Systems Engineering, 2008), but the point here is to reflect on this course and the opportunity it provides to diagnose difficulties in engineering education.

Think about it. Here we have students prepared in a fairly typical engineering curriculum who go to work for the first time on a real engineering problem. It is the perfect opportunity to ask, "What don't they know how to do?" As a faculty advisor in Senior Design since 1990, I have learned how to coach students to successfully solve their problems, but I am continually reminded, year after year, about the mismatch between the education a cold war curriculum provides and the demands of a real-world engineering problem. The next section considers what is missing.

Seven Failures of Engineering Education and the Missing Basics

The semester has begun. The projects are assigned, and teams of three student engineers and their advisors are ready to go on the plant trip and find out what the project is really about. Over 19 years of advising such teams, I have found seven important skills that students have difficulty with. Although there is significant variation, the following composite set of difficulties is common enough that most teams require coaching along many, if not all, dimensions discussed.

In particular, senior design students have difficulty

1. *asking* questions
2. *labeling* technology and design challenges
3. *modeling* problems qualitatively
4. *decomposing* design problems
5. *gathering* data
6. *visualizing* solutions and generating ideas
7. *communicating* solutions in written and oral form

Each of these is briefly considered in turn, associating each of these failings with a prominent name in intellectual history (Solomon and Higgins, 1996):

Questions. Students go on the plant trip, and the first job is to learn what the project is, what has been tried, what critical sources of data and theory exist, and what vendors have been helpful in solving related problems. Unfortunately, most student teams have trouble asking cogent questions. We call this a failure of *Socrates 101* in recognition of that philosopher's role in teaching the world to ask.

Labeling. Engineering students learn math and science but are largely ignorant of technology itself, exhibiting difficulty in labeling the components, assemblies, systems, and processes in their projects. Moreover, many projects exhibit novel patterns of failure or design challenge, and the students have difficulty *giving* such patterns names and sticking to those names. This we call a failure of *Aristotle 101* as the systematic naming and categorization of concepts is often attributed to that philosopher.

Modeling. With sufficient coaching, students learn the names of extant components and processes and are able to give names to novel patterns, but then they have difficulty modeling design challenges *qualitatively.* Of course, if the problem lends itself to simple calculus or physics computation, engineering students can plug and chug with the best of them; however, companies do not pay real money for someone to do routine engineering calculation. Where students have difficulty is in making lists of system elements or problem categories or in describing how things work in words. This is a failure of *Aristotle 102* or *Hume 101* because of the connections of those philosophers to categorization and causality.

Decomposition. With some help in understanding key causal and categorical relations the student engineers regain their footing, and then they have trouble decomposing the big design problem into smaller subproblems. We call this a failure of *Descartes 101* because of that philosopher's discussions of the fundamental role of decomposition in the solution of problems.

Gathering data. With the job separated into pieces, usually a number of the pieces depend on careful data collection from the literature or from the design and execution of careful experiments. The students' first impulses are often to model mathematically, but an efficient and effective solution often depends on simple experimentation or library work. We call this failure to resort to empirical work or extant data a failure of *Galileo* or *Bacon 101* because of these individual's contribution to the creation of systematic empirical science.

Visualization and ideation. Students have trouble sketching or diagramming solutions to problems, and more generally they have difficulty in brainstorming a sufficiently large number of solutions. Calling this a failure of *da Vinci 101* because of that individual's renowned imagination and ability to visualize, the problem again is solved with some coaching.

Communication. Finally, the students have solved the problem, done the experiments, put together the analyses, and largely solved the problem, and the time has come to make a presentation or write a report, and to quote the famous line of the Captain from the movie *Cool Hand Luke,* "What we've got here is a failure to communicate." Calling this a failure of *Newman 101* (Paul Newman), the situation again calls for significant coaching.

By associating important figures in intellectual history with each of the seven thinking skills, the listing emphasizes the basic nature and importance of each of the skills. Socrates, Plato, Aristotle, and other Greek philosophers helped launch human thought on a particularly productive 2,500-year stretch of creative dialectic. The thinking skills established and refined at that time of the Greeks, as well as the others in the list of seven, are among the most basic and important habits of thought known to humankind, and so it should cause particular chagrin that engineering students get to the end of a traditional engineering education unable to effectively exercise those skills in the practice of their chosen discipline.

These failures are substantial – certainly they are as much a failure of general education as engineering education – and a senior design faculty advisor helps his or her team by providing just-in-time coaching in the missing basics, as needed. Yet, in one sense, it is quite difficult to understand how such a situation could possibly have arisen. After all, don't engineering faculty members take great pride in teaching a "rigorous" curriculum full of "the basics." And if "the basics" are taught, shouldn't engineering students be able to perform the rudimentary requirements of a real engineering problem in a senior design project without heroic coaching in the needed skills?

The problems here are real enough, but note how the difficulty is exacerbated by the *language* engineering academics use. When engineering faculty talk about "the basics," they are referring to mathematics, science, and engineering science. These subjects are important, but in the context of the current discussion, are they really the most basic subjects critical to being an engineer? This paper argues that they are not, that the seven thinking skills constitute the *missing basics* of engineering education, that the missing basics are fundamental to understanding "the basics," and that engineering education needs to change its thoughts, language, and practices to make the missing basics more central to the engineering canon.

Given that there are linguistic obstacles and a general lack of conceptual clarity in the discussion, it is important for us to understand the origins of the current strains of thought in engineering education and to remove obstacles to clarity in thought, language, and action. These are the tasks taken up in the next section.

Removing Conceptual Hurdles to the Missing Basics

The previous section used an industrial-sponsored, real-world senior design course as a way into understanding some of the shortcomings of engineering education today, and the results were damning. Faculty members defend a "rigorous" curriculum devoted to "the basics" but engineering students have trouble asking questions, naming extant technology or novel technological phenomena, explaining how things work, breaking big problems into solvable little problems, brainstorming and visualizing, and communicating effectively with speech or the written word. For some time, there have been increased calls for reform, and strenuous funding and programmatic efforts have been directed at fixing engineering education's problems, but the situation remains much as it was.

The previous section suggested that a good part of the difficulty is a lack conceptual clarity in discussions of the fundamentals of engineering education. Human practices can often be better understood by probing their history, and here we start historically and attempt to find the origins of our current educational practices. The section continues its reflection sociologically by examining how sets of social practices can take on a logic of their own, examining Kuhn's work on paradigms and change in science in the context of engineering education. The section concludes by examining how the engineering academy defines the practice of engineering as applied science, thereafter offering a definition of the discipline that is arguably better aligned with engineering as practiced. Although engineering academics with low regard for "soft" subjects may be dismissive of an analysis that relies so heavily on historical, sociological, and philosophical modes of reflection, the inconsistencies revealed already in this paper and those uncovered in the remainder suggest fairly convincingly that the apparent reliance on more "rigorous" modes of thought by academics steeped in "the basics" has been more or less inadequate to the needs of effective curriculum design; here we are unapologetic in using thinking tools appropriate to the task at hand (Schön, 1983; Toulmin, 2001).

A Cold War Curriculum in an Internet World

The subsection title asserts that engineering education is stuck in a cold war time warp, and this begs us to briefly examine events following World War II, consider the missed revolutions that occurred between then and now, and assess major trends of our times.

The Forces Shaping the Cold War Curriculum After World War II

Engineering as taught today can be understood as a response to the technological and economic forces in place after World War II. At that time, economies of scale were dominant, large hierarchical organizations were the rule, and engineers became increasingly scientific in response to perceptions of the high status of science after the war. Whether this status was deserved and whether the reaction should have been as strong as it was can be debated (Goldberg, 1996); however, there is little doubt that these tendencies were reinforced by governmental actions (Bush, 1945) that funded basic scientific research in post-war government labs and universities, thereby encouraging academic engineers to join what was then a new money chase.

The Missed Revolutions

The previous paragraph may raise concerns among some readers, because seeking fame, status, or money directly often turns out badly, but it is quite reasonable to see the post-war move toward specialization and science as an appropriate response to those times. In an era of Sputnik, the cold war, and continued growth in mass production, the idea of large numbers of specialized engineers working out narrow, technical puzzles posed by their business and bureaucratic managers in large hierarchical organizations is a reasonable model for the organization of engineering work, but time did not stand still, and what once made sense in that era has been overturned by what has elsewhere (Goldberg, 2007a) been called the three *missed revolutions.* We will not review these in detail here, but the quality revolution, entrepreneurial revolution, and information technology revolutions have changed the nature of how companies are organized, how they are started, and how they communicate and coordinate their work products with suppliers and markets. The revolutions are "missed" in the sense that the academy teaches elements of quality methods, entrepreneurship, and information technology, but it tends not to integrate the lessons of the missed revolutions into its own business. The point to keep in mind is that much has changed since the 1950s, and an engineering curriculum formed in response to the economic and technological forces of those times may have some problems in the present.

Our Creative Era

In turning to our circumstances today, a number of current authors (Florida, 2002; Friedman, 2005; Pink, 2005) have looked at the globalizing technological and economic changes around the world and concluded that returns to routine analytical work, including engineering, are diminishing, and returns to *creativity* are increasing.

A distinction can be made between *category enhancers*, workers who primarily improve upon existing category of products, and *category creators*, those who develop and market successful new products and services. The mental image of an earlier paragraph of hoards of engineers working in vast corporate enterprises has given way to images of engineers starting new companies in Silicon Valley or even engineers in larger companies working with marketing and customers to forge new features, products, or services.

The analysis here is not suggesting that all engineers should be or become category creators, pure, and simple; however, in a world with opportunities for both enormous creativity and technical prowess, it seems clear that we should not box our students into a model tuned to earlier times when prowess was valued above all else. Moreover, the missing basics are exactly those critical and creative thinking skills that tie science and mathematics to the other things an engineer must think about, know about, and act upon, and even in large hierarchical settings, engineers trained in the missing basics are better able to relate their work to a larger whole.

Kuhn, Paradigms, and all That

These historical analyses help put the past and present in perspective, but they do not explain why practices and attitudes forged in the crucible of World War II and the cold war continue to grip the minds of engineering academics today. To understand this, we must make what is ultimately a sociological move, by turning to Kuhn's famous book, *The Structure of Scientific Revolutions* (1962) to consider his notions of a *paradigm* and *normal science* and apply them to better understand how change in thinking comes about in the engineering academy as a social process.

Briefly, Kuhn argued that science does not progress smoothly, but rather, it progresses in fits and starts. At a given point in time, a dominant model or paradigm of some science exists (for example, Newtonian physics), and the mass of researchers in that science work within the boundaries of that paradigm – they do normal science – unquestionably extending the reach of that science by solving the *puzzles* posed by the paradigm's methods, rules, or laws. Over time, *anomalies* arise within the paradigm that cannot be explained within the paradigm (motion near the speed of light), and theories arise to explain these anomalies (relativity). Two key points to keep in mind are that anomalies often persist without explanation for some time and that new theories are not generally warmly greeted. Eventually, the evidence for new theories becomes overwhelming and the mass of scientists change their minds, not gradually, but in an avalanche of revision.

In the setting of engineering education, we may think of the notion of the engineer as applied scientist as the dominant paradigm of engineering education. It arose in the aftermath of World War II, and the term "physics envy" captures the dominant value and energizing motive behind the mind of the engineering academic. When engineering faculty talk of "rigor" and the importance of "the basics," they may believe they are making an argument; however, they are speaking largely as defenders of the paradigm. If they are making an argument, it is largely an *argument from authority* (Rosenberg, 1984), the vague social authority of the paradigm, not a specific argument with explicit warrants or independent backing (Toulmin, 1958).

Moreover, in asserting the supremacy of "the basics" engineering faculty can become quite smug and superior in their tone, but there is delicious irony in these assertions, and one thing should be made clear. The support of the "the basics," regardless of the passion of the defender or the degree of haughtiness of tone, is not itself scientific. Where are the data behind the assertions? Where are the careful statistical studies and *t*-tests? For the aficionado of mathematics, where are the axioms and proofs that lead to conclusions about the superiority of these modes of thought. For the physics minded, where are the equations of motion of engineering education that govern how educators, students, content, and curriculum interact?

The simple answer is that none of these things exist. Moreover, given that the tools so prized by the defenders of the basics are not applicable to the educational design problem at hand, the previous paragraph amounts to an existence proof that certain things defy "rigorous" notions of thought using only "the basics." This point is made even more forcefully elsewhere (Goldberg, 2009a) through a critical examination of the terms "rigorous," "the basics," and "soft." We will not follow the argument in detail here, but with reasonable interpretations of those terms and the added assumption that engineering is practiced in an environment of limited resources, the paper concludes that engineering restricted to a "rigorous" form of the "basics" is inconsistent with the needs of practice. This leads to the suggestion that there is a certain incoherence among engineering curriculum discussions that has largely gone unnoticed, and that engineering faculty members who continue to defend an unexamined faith in "rigor" and "the basics" are guilty of what can be called a certain carelessness of thought. Put another way, those who defend mathematical or scientific rigor against all comers are guilty of a certain kind of philosophical illogic or "softness:" they are making bad or null arguments.

These are strong statements, and I should be careful to add that I respect mathematical and scientific knowledge and knowhow as *part* of what it means to be a good engineer, that I believe we must continue to provide a full measure of mathematics, science, and engineering science education at the undergraduate level; however, to largely equate engineering and applied science and to exclude other modes of thinking important to the practice of engineering are mistakes of striking proportions.

Is Engineering Merely Applied Science?

The previous two sections have scrutinized the origins and persistence of current engineering education practice, finding both to be suspect or wanting. In particular, the post-war idea that "engineering is merely applied science" seems to be quite powerful and enduring. Here, we argue that the idea is widely held in the academy and *philosophically* mistaken. The section starts by offering an analysis of the words and actions of engineering academics, continues with an analysis of the senses in which the term "merely" is used, finding none of them to be acceptable, and then concludes offering a different definition of engineering that results in an actionable threefold decomposition useful for thinking about educational reform.

Engineering Academics Do Believe That Engineering Is Merely Applied Science

The idea that engineering is merely applied science is widely held in the engineering academy, and faculty members involved in engineering education show their true colors and defend the assertion in a variety of ways. Already this paper has mentioned the steadfast use of certain terms such as "rigorous" and "the basics" but there are other examples. For example, engineering academics defend "the basics" against the encroachment of "soft" subjects, and it is even fairly common for engineering faculty to ridicule "soft" subjects and those who teach them; it is the rare engineering department, indeed, that can bring itself to approve course offerings in "soft" subjects and even rarer for engineering colleges to find it acceptable to offer tenure to those with "soft" disciplinary backgrounds. Moreover, the proportion of "soft" subjects in the traditional engineering core is negligible, and tolerance for additions to the "soft" courses outside the core is low.

Although not definitive, the examples above, these choices by academic engineers of routine terminology and actions in the face of important decisions relative to curriculum planning, coursework, and resource allocation, suggest that engineering academics do tend to believe that "Engineering is merely applied science;" however, there remains just one little problem. The idea is profoundly mistaken. To get at this category error, the remainder of the section examines what is usually meant by the term "merely," finding it to be a word of disparagement, containment, or the assignment of temporal priority.

An Analysis of the Term "Merely"

"Merely" is an interesting word. First and foremost, the term is used as a kind of putdown, meaning to disparage the subject of the sentence relative to its object. So when we say, "Engineering is merely applied science," we elevate science and deflate engineering. Elevating pure thought and disparaging thought in application has ancient roots in the Western tradition, as the Greeks were fond of elevating pure philosophical speculation by wealthy gentlemen (or those who had patrons among them) over the workaday thoughts of craftsman and workers, many of whom were less wealthy or slaves. Although the intellectually arbitrary and self-serving class distinctions made by slaveholding gentleman two and half millennia ago may have been useful to them, it is not clear why the cultural predilections of a society so unlike our own continues to cast this particular spell upon us, but culture is nothing if not persistent.

Of course, the term "merely" can mean more than just a simple putdown. "Merely" can also mean something like "simply," "largely a matter of," or "is contained in." Here the intent is less pejorative, but more of an attempt to restrict the subject to the contents of the object. In this sense of the term, the sentence

"Engineering is merely applied science" suggests that engineering is contained in or largely a relatively simple matter of applying science. Walter Vincenti's (1990) important book *What Engineers Know and How They Know It* argues strenuously and persuasively against this point of view, showing that the artifacts of engineering knowledge in the traces of aeronautical history are distinctly different from the artifacts of scientific knowledge. This is not the time or place for a detailed examination of his arguments; however, Vincenti seeks to *demarcate* engineering knowledge from scientific knowledge in ways analogous to the efforts of scientists and philosophers of science seeking to demarcate science from non-science (Kasser, 2006).

Finally, any sense that science predates the engineering of technological artifacts is just historically inaccurate. The systematic design and production of relatively complex technological artifacts goes back 2.5 million years in human history to the Stone Age with the manufacture and use of stone axes by our early human ancestors (Fagan, 2003). Systematic science does not really start until the middle of the second millennium or thereabouts, and one of the fathers of modern science, Sir Francis Bacon explicitly credited the method of the *mechanical arts* of his time for suggesting the way toward a more systematic scientific method (Goldberg, 2006). In other words, if we were to follow Bacon, and give credit where he thought credit was due, we might turn around the locution "Engineering is merely applied science" and say that science is merely the application of engineering method to the evolution of models or concepts.

Thus, our deconstruction of the sentence, "Engineering is merely applied science," is complete and none of the three interpretations makes much sense. The putdown by the lofty of the applied is a class distinction with suspect roots in a slaveholding society much different from our own. The idea that engineering is contained in science is problematic because engineering knowledge has differences when compared to the scientific kind, and the thought that engineering is predated by science is just flat wrong. No doubt engineering uses science, but the real problem here is that this lazy definition does not fully capture much of what engineers do in practice, a problem taken up next.

A View from Engineering Practice

In philosophical terms, the view of engineering as applied science is a bit odd, because it conflates one of the tools used in making technological artifacts, systems, or processes – science – for the end goal of the activity. In philosophical terms, science is *instrumental* to the products of engineering but it is not the product itself. While it is true that there are times in history that particular artifacts are enabled by scientific discovery, it is equally true that there are times in history where scientific advance is enabled by technological artifacts and instruments. Thus, since we define science in terms of its end products, methods, and actors – scientific knowledge, method, and scientists – it seems reasonable and fair to define engineering in terms of its end goals, methods, and actors as well.

Thus, we might choose to define engineering as follows (Goldberg, 2009b):

> *Engineering is the social practice of conceiving, designing, implementing, producing, and sustaining complex technological artifacts, processes, or systems.*

Engineering is largely concerned with making things that help people, where the term “things” is broadly construed; however, the things are not simple things, easily made, but rather they are complex things requiring certain special tools and knowhow to make them. Moreover, the things are not static objects of art or aesthetic appreciation; they are used in some manner or they do something or “work” in some way.

There are a variety of tools, knowledge, and knowhow that go into the engineering process, and those actions are themselves generally fairly complex, drawing on many different realms of human knowledge as well as specialized knowledge and practices developed within engineering itself.

The complexity of engineering is such that it is generally a social undertaking. In small settings, at a minimum, engineering involves the maker and the individual for whom the thing is made, but even this minimalist setting has hidden social complexity in both the web of suppliers that aid the engineer in the production of the artifact as well as the intended and unintended consequences of the use of the artifact by the client in a larger social context. In larger settings, the “social practice” can take on an almost unlimited social complexity, involving a multi-path and multi-step chain from maker to user, moderated by and affecting many institutions, populations, and individuals along the way.

Thinking about engineering this way leads to a different, more balanced conception of engineering and engineering education than is usually proposed. In particular, a threefold decomposition of engineering education called *3Space* (Goldberg, 2009b) recognizes the complexities inherent in the definition above by moving away from an analysis-centered position to one that balances the habits of thought needed to create things in a world of people as follows:

- *ThingSpace:* Engineering creates complex technological things (artifacts, processes, or systems).
- *FolkSpace:* Engineering is an activity performed by, for, and with people.
- *ThinkSpace:* Engineering is a complex process of intertwined thought and action, involving math and science as well as many other critical and creative thinking skills.

We will not elaborate on these here, but the decomposition invites further hierarchical decomposition.

Why Philosophy? Why Now?

When I helped organize the first Workshop on Philosophy and Engineering held in 2007, I thought long and hard about what paper I would present, and I chose to take another page out of Kuhn’s playbook and make an argument about why engineers might be turning to philosophy at this juncture in history (Goldberg, 2007b). Although many remember Kuhn for his notion of paradigms invoked earlier, some forget that he also made an argument to explain why scientists became interested in the philosophy of science in the opening moments of the 20th century. Simply put, Kuhn argued that the disruptive nature of the new physics shook what scientists took as given: long-held notions of space, time, and causality. Kuhn argued that scientists turned to philosophy of science as a way of both understanding the crisis of thought they were going through and as a way to help other scientists make the transition to the new thinking.

That 2007 talk argued by analogy to Kuhn, suggesting that the rapid pace of technological change in the opening moments of the 21st century is as disorienting to engineers as those earlier times were for scientists. It is in this spirit that I think philosophical reflection is particularly important for engineers right now. As I have suggested, whether you believe the cold war paradigm was appropriate to the 1950s or merely a category error, even then, is immaterial. The signs are clear that the old paradigm is breaking down and that new ways of thinking about what it means to be an engineer are emerging from the pace, scope, and sweep of technology in our times.

Against this backdrop, the need for conceptual clarity is greater for engineers now than it has ever been, but it is really troublesome to see such a paucity of good argument, especially at this moment in history, and to see the repeated and not very imaginative defense of the status quo through the invocation of tired code words. To be clear, it seems that it is incumbent on defenders of the cold war paradigm to do something more than call for "the basics" and denigrate certain thoughts by calling them "soft" or "not rigorous."

To raise the quality of argumentation in our community requires more of us to make better arguments. I hesitate to use the term, but in a very real sense, I am calling for a more rigorous mode of conceptual discourse in the engineering academy, and philosophy and related subjects have a role to play in offering appropriate models and methods. Typically, introductory non-symbolic logic courses in philosophy teach the basics of analyzing and making arguments in words, covering many of the common fallacies, and considering the basics of form and support. Argumentation courses in communications or similar departments (Zarefsky, 2001) do likewise, oftentimes building on Toulmin's (1958) model in a unifying way that can be satisfying to mathematicians and lawyers, both.

Moreover, given that the missing basics involve qualitative thought and argumentation applied to engineering problem solving in a very real way, our efforts as engineering academics to make better arguments amongst ourselves may pay off in the discovery of new teaching methods that will help us convey the missing basics more effectively to our students.

These prospects are exciting ones. The path to engineering education transformation is difficult, and there is no single exertion that will set us on the royal road to effective reform; however, a good step along the way is to clear the air philosophically so that we do not remain trapped in the conceptual errors of the past.

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