Track 15: Reflective Engineering

# Engineering Rigor and Its Discontents

Philosophical Reflection as Curative to Math-Physics Envy

**David E. Goldberg**
Illinois Foundry for Innovation in Engineering Education (iFoundry)
University of Illinois at Urbana-Champaign
Urbana, IL 61801 USA
deg@illinois.edu

Engineers, particularly the academic variety, are fond of using the term "rigor." Rigor is generally considered a good thing and it is used to construct phrases of approbation. "That's a rigorous analysis" or "He had a rigorous education." Its absence is considered to be a bad thing, and then the term can be used to construct phrases of derision: "Those leadership and teamwork classes are not sufficiently rigorous to be taught in the College of Engineering." With some frequency the term "soft" is used as synonymous with "not rigorous" as in "We'll accept those soft courses in a rigorous engineering curriculum over my dead body."

This paper considers the different ways in which the terms "rigorous" and "soft" are used in engineering circles with an eye to understanding the biases reflected in such usage. The paper starts historically and traces the beginnings of this way of thinking to the importance of Maxwell's equation to early electrical engineers at the end of the 19th century and considers the engineering education's wide adoption of more math and science following World War 2 as the most recent contributory event to this trend.

Thereafter the paper shifts to consider two senses of the term "rigorous." The first sense is the mathematical one, and the idea is that one is *rigorous in derivation* or in the giving of a formal proof. In other words, one is being rigorous in this sense if one starts from a well defined set of premises, moves step by step using the laws of symbolic logic, coming to a correct and formally true conclusion at the end. Here, we pause and reflect that although aficionados of rigor in derivation take pride that formal proofs result in conclusions that can be traced back to the original premises with nothing added, that argumentation theorists criticize formality on exactly the same grounds. Toulmin's argument (Toulmin, 1958) is often used along these lines, and there the notion of *modus ponens* is augmented with the addition of a *warrant* in which other inputs can be used from outside the premises to support or bolster the conclusion.

The second sense of rigor is the scientific one, and the idea is that one is *rigorous in application of established scientific laws*. In other words, one is being rigorous in this sense if one starts from a set of scientific laws and moves to an answer using the rigor in derivation discussed in the previous paragraph. Seen in this light, an aficionado of the first type of rigor might object to the use of mere constant conjunction (to use Hume's term) of certain causal patterns to rely on the inductive speculations of science. It is also interesting to note that the term "rigorous" is not usually applied in this sense when the principles of science are not represented as mathematical laws. For example, the notion of plate tectonics in geology is not usually expressed in law-like form, and it would be difficult to find a geologist anywhere who would diminish the importance of that discovery in explaining so much about the world around us. Yet it would also be difficult to find an engineer who would use the term "rigorous" in the context of plate tectonics or any theory expressed in largely conceptual terms.

This last observation gives us a clue as to the problem, and it is one recognized and elegantly attacked by Toulmin (2001) and Schon (1983). The problem stems from an overemphasis in representing knowledge in the style of physics since Newton. The paper explores Toulmin's historical tracing as well as his argument for *reasonableness*. It also considers Schon's argument for more *reflective practitioners* who put math and science in their proper place as one set of tools among many. The paper finds these two perspectives to be simpatico and palliative, but it also recognizes that those who live by equations and numbers are unlikely to be persuaded by mere arguments and words.

The paper continues by summarizing an economic theory of models presented elsewhere (Goldberg, 2002). Starting from the assumption that engineers often work in economic settings, the paper reviews a theory of modeling that looks at the tradeoff of modeling prediction error and cost. It then examines the circumstances under which an engineer is being economic in his or her modeling, arguing that many times, the use of rigorous models (in the two senses above) is uneconomic. This conclusion leaves a "rigorous" engineer in a precarious position. Either he or she isn't much of an engineer (in the economic sense) or the restriction to the two modes of rigor discussed at the outset is too limiting.

The paper takes the second way, and the economic analysis together with the arguments of Toulmin and Schon pave the way to a reconsideration of the usual notions of engineering rigor. The paper concludes by suggesting that philosophy has a number of important roles to play in sorting out these longstanding conceptual errors, not the least of which is offering alternative forms of rigorous analysis to those who may soon discover the limitations of their earlier mistaken beliefs.

## References


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