[Extended Abstract]

What Engineers Don't Learn and Why They Don Learn It:

and How Philosophy Might Be Able to Help

David E. Goldberg
University of Illinois at Urbana-Champaign
Urbana, IL 61801 USA
deg@illinois.edu

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1. INTRODUCTION

Once again, reform of the engineering curriculum 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 [1], and one calling for changes in the ways young engineers are educated [2]. A national engineering leader has independently called for significant reform [3], and the Olin Foundation has given $460 million dollars to establish a pioneering new curriculum at the Franklin W. Olin College of Engineering [4]. 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 [5].

Although much money, time, and effort has been expended toward engineering curriculum reform, and some successful reform has been achieved, it is not clear that the writing and doing to this point have clearly articulated the central problems facing engineering education today. The purpose of this talk is to approach the problem philosophically and reflect on what engineers don't learn as part of the usual engineering education and then to consider five reasons why engineering students don't learn these things.

I start by considering the interesting opportunity for reflection afforded by the juxtaposition of a fairly standard cold war engineering curriculum and a quite modern and effective industrially sponsored senior design project course. I continue by asking what skills appear to be missing among engineering students who have successfully completed such a curriculum as they approach real-world projects. That inquiry leads to the conclusion that very basic critical and creative thinking skills are being missed, and the talk continues by asking for possible explanations of how such basic skills are not being taught or learned. Five reasons are examined, and the talk concludes by asking how philosophy might be useful in rectifying the current situation.

2. COLD WAR MEETS SENIOR DESIGN

The "standard" engineering curriculum of our time was largely set in the aftermath of World War 2 during the opening days of the cold war period of the 1950s. In the US, the Grinter report [6] 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 [7]. 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 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 [8], but the point here is to reflect on this course and the opportunity it provides to diagnose difficulties in the engineering curriculum. 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 learn?" As a faculty advisor in Senior Design since 1990, I've 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's missing.

3. 7 FAILURES OF ENGIN EDUCATION

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 18 years of advising such teams, I've found seven important skills that elude many students. Although there is significant variation, the following composite set of difficulties is common enough that most teams require coaching along most, 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.

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 his role in teaching the world to ask.

Labeling. Engineering students learn math and science but are largely ignorant of technology itself and have difficulty labeling the components, assemblies, systems, and processes in their projects. Moreover, many projects provide novel patterns of failure or design challenge, and the students have difficulty *giving* such patterns consistent names. This is 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 give names to novel design challenges, but then they have difficulty modeling design challenges *qualitiatively.* 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 don't pay real money (currently $8,500) for someone to do routine engineering calculation. This is a failure of **Aristotle 102** or **Hume 101** because of the connections 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.**

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 a failure of **Bacon 101.**

Visualization & 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,** 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 faculty intervention.

4. WHY THEY DON'T LEARN IT

These failures are substantial, and they are as much a failure of general education as engineering education, but if an industrial product were to come off the assembly line with defects in intended functionality as substantial as these, we would be forced to admit that the design and assembly process was subject to a massive failure in quality control.

The more interesting question, however, is how such a failure has come to pass. The talk addresses five reasons why the curriculum doesn't teach the right stuff:

Engineering mistaken for applied science/math. Engineering educators bought the mistaken cold war idea that engineering is essentially applied math and science (Vincenti, 1990).

Engineering reasoning and epistemology not articulated. One of the reasons why engineering could take such a wrong turn post war is that it did not articulate a strong alternative vision of how it thinks and what it knows.

Pedagogical solutions to philosophical problems. The literature of engineering education emphasizes pedagogy and assessment, and largely assumes that engineering content is correct and settled.

Almost no attention to organizational reform. Reform efforts assume that existing departmental structures are adequate for supporting change.

Scalability of reform efforts ignored. Many reform efforts assume unrealistic or unsustainable influx of funding or substantial changes in faculty attitudes.

The talk examines each of these in additional detail.

5. HOW PHILOSOPHY MIGHT HELP

Philosophy is important to repairing these difficulties, directly and indirectly. Better understanding of intellectual history and philosophical method should help fill the seven critical lacunae. Of the five problems of the last section, three are significant category errors that can be overcome by more careful reasoning. The talk concludes by suggesting that improved engineering education can be an important outcome of the current interaction of philosophers and engineers

6. REFERENCES

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