The Engineering Way of Thinking: The Idea

By William M. Bulleit, Ph.D., P.E.

At the 2013 annual meeting of the National Academy of Engineering in Washington, DC, Mitch Daniels, the former governor of Indiana and the president of Purdue University, said this about the possibility of educating too many engineers: "But even if we were to somehow outrun the market's need for engineering talent, we will be a far stronger country if the engineering mentality takes a more prominent place in our national conversation."

I would like to consider what Daniels called the 'engineering mentality' more broadly and refer to it as the "engineering way of thinking" (EWT). Like Daniels, I believe that more widespread use of the EWT will benefit society. For many if not most Americans, this idea makes no sense, is absurd on the face of it, or is potentially dangerous. I suggest that the naysayers are wrong, either because they are ignorant about engineering or are looking at engineering and engineering knowledge through mid-20th-century glasses that distort their view of what engineering is supposed to entail.

Engineering is constantly evolving, and the main driver for that evolution is the emergence of better heuristics for design. Heuristics are techniques – colloquially, rules of thumb – that allow problems to be solved that would otherwise be intractable. Heuristics range from very crude techniques to very sophisticated methods. Billy Koen has said repeatedly that the engineering method is to use heuristics, but the EWT is more than just using heuristics. It encompasses how we choose which heuristics to use, what kinds of heuristics we use, how we use the heuristics that we choose, when we change heuristics, how we change heuristics, and why we change heuristics. To be fair to Koen, I suppose that we use heuristics – or perhaps "meta-heuristics" – to do all of these things.

None of the above decisions can be made without first thinking about design. Design is the process of taking something that appears in the mind's eye, modeling it in one or more of a number of ways, predicting how that thing will behave if it is made, and then making it, sometimes modifying the design as we make it. Design is what engineering is about. Furthermore, modeling is how engineering design is done. This includes mental models, mathematical models, computer models, plans and drawings, written language, and (sometimes) physical models.

Engineering is constantly evolving, and the main driver for that evolution is the emergence of better heuristics for design.

Some historians of technology claim that what the Egyptians did to build the pyramids was not engineering. Certainly it was not engineering as we know it today, but it was indeed engineering. The pyramids were imagined, modeled in some way – probably with drawings – and then built. For its day, it was sophisticated engineering. The engineering ability of the Egyptians must have evolved from the first use by some hominid of a tool to do something, as well as the more sophisticated tools used in Egypt and elsewhere before the building of the pyramids.

Of course, engineering continued to evolve after the pyramids. From the Middle Ages, we have massive masonry buildings – e.g., cathedrals – in which post-construction efforts to fix inadequate design were used, such as flying buttresses. These are a good example of another aspect of the EWT: learn from failure. In this case, many of the failures were (fortunately) non-catastrophic.

Engineering continued to evolve, often in the context of military applications such as siege weapons and fortifications, up to and through the Renaissance, primarily as something that looked more like a trade than what we today call engineering. Strength of materials first developed as an analytical tool during the Renaissance. Of course, many other ideas and mathematical methods became available during that era and thereafter. Some of these proved useful for designing new artifacts such as the steam engine. Engineering began to use ideas and heuristics that had been unavailable in the past. This step in the evolution of engineering represents another aspect of the EWT: If an idea appears useful, try it.

The heuristics available to engineers advanced even more rapidly as the end of the 19th century approached. We refer to that time as the Industrial Revolution. It was then that engineering science became a distinct field. At that time, it was used only to a limited extent in engineering proper; widespread use of it was yet to occur. Engineering education was still emphasizing the trade origins of engineering. Engineering students still took a significant amount of shop courses and drafting.

It was not until after World War II that engineering science became the primary component of engineering education and an integral aspect of engineering practice. Once again, the heuristics for design were evolving. This evolution continued with the advent of the computer, and continues today. If a tool appears to be useful, try it. If it works, use it. This approach is a major aspect of the EWT, and goes beyond just trying tools. It includes trying new ways to design and build the myriad of artifacts that engineers develop.

The EWT is something that the community of engineers uses and keeps alive. As individual engineers, we use only a small portion of the EWT, but we all need to be aware of it and learn more about it. The EWT is both science and art, both theory and practice, both analysis and synthesis, both philosophy and common sense, and more. It expects that methods and ideas will continuously evolve, and that much of that evolution will be driven by failures, both large and small. The EWT has been much maligned and often ignored. I will address it further in my next column.▪

*William M. Bulleit (**wmbullei@mtu.edu**), is a professor in the Department of Civil and Environmental Engineering at Michigan Tech in Houghton, Michigan, and the vice chair of the SEI Engineering Philosophy Committee.*