The Engineering Way of Thinking: An Analysis

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In two previous columns ("The Engineering Way of Thinking: The Idea," December 2015; "The Engineering Way of Thinking: The Future," January 2016), I discussed the idea of the engineering way of thinking (EWT) and what it might bode for the future. This column is an analysis of the EWT, performed in a manner similar to how the philosopher Ludwig Wittgenstein – who received his initial education in engineering – might have gone about it. It consists of a number of statements organized in a way that I hope will lead you to a better understanding of the EWT.

1. Engineers want to make something – an *artifact* – or want to alter an existing artifact.

1.1. Artifacts can be objects, processes, or systems – a combination of objects and processes.

2. Making or altering artifacts means perturbing reality.

2.1. Any perturbation of reality involves *uncertainty*, often a significant amount of uncertainty.

2.2. Making or altering an artifact requires planning and prediction, in part to deal with uncertainty.

2.2.1. The planning and prediction for making or altering an artifact is *design*.

2.2.2. Design requires a will to make or alter an artifact.

3. The actual making or altering of the artifact comes after the design and is *construction, fabrication, manufacture, implementation, instantiation*, etc. It requires tools that are also a part of engineering.

4. The EWT involves all methods, techniques, thought processes, and so on that are used to make or alter artifacts.

4.1. The EWT also involves meta-efforts to turn the EWT back on itself. The EWT is itself an artifact.

4.2. The EWT must draw on a wide range of disciplines to allow engineers to make or alter artifacts. These include, but are not limited to, mathematics, physical science, natural science, engineering science, engineering technology, written and oral communication, philosophy, psychology, manual labor, equipment operation, trades such as welding, group dynamics, economics, computer-aided design and drafting (CADD), building information modeling (BIM), 3D printing, and so on.

4.3. The EWT requires that engineers develop mental models based on a wide range of disciplines, and that they continually broaden those horizons.

5. The EWT draws on these disciplines using pragmatic criteria: If it looks like it might work, try *it*. If it works, use *it*.

5.1. In design, the "its" are often referred to as *heuristics* – things that help to make tractable the kinds of problems that are intractable from a purely mathematical or scientific viewpoint.

5.1.1. The heuristics used in design have limits. These limits may be readily apparent, or not in the least bit apparent.

5.1.2. Exceeding the limits of heuristics leads to *failure*, potentially catastrophic, but often non-catastrophic.

5.1.3. Failure means that the heuristic must be re-examined in light of its being *falsified* in some sense.

6. Normal or day-to-day engineering generally limits itself to heuristics that have not been falsified by failures, at least for the range in which they are being used, and thus are supported by the engineering community.

6.1. Normal engineering is focused on getting the job done. This part of the EWT, getting the job done, is often considered *engineering proper*. Getting the job done is engineering, but it is not all of engineering, and it certainly is not the EWT; it is just a part of the EWT.

6.2. Normal engineering is a heuristic within the EWT.

7. No individual engineer uses the entire EWT, any more than any individual engineer uses all available engineering technical knowledge.

7.1. The EWT encompasses all tools used presently by engineers, all tools used in the past that might be used again, and all new tools that might be used in the future.

7.2. The EWT *evolves* when engineers, both individually and in groups, try new, previously untested tools to make or alter existing or new artifacts.

7.2.1. New artifacts may be ones that have existed for some years, but have never been examined by the EWT (e.g., social systems), or ones that have never before existed (e.g., quantum computers).

7.2.2. An engineer's discipline, or even subdiscipline, should be a base camp from which to explore the peaks and valleys of the EWT.

8. Designing artifacts often requires some amount of reduction of the system to a *control volume*; e.g., a beam in a building or a pump in a water system.

8.1. A control volume can also be a reduced time frame. A simple example is a 50-year design life. In more complicated systems, the control volume might be determined by a *prediction horizon*.

8.2. A prediction horizon is the point in time at which predictions of the entire system behavior become so uncertain that they should no longer be used in design decisions. As the EWT is applied to complex systems, such as the earth's climate and its interactions with human society, control volumes based on appropriate prediction horizons will be vital to engineering design.

9. Designing artifacts is by nature *reductionist*, since control volumes are necessary.

9.1. The need to be reductionist must be continually reassessed, otherwise we will miss the forest by focusing on the trees.

9.2. Using a control volume of an artifact to allow manageable analysis is a heuristic that is used in normal engineering and is widely applicable to the EWT.

10. Most, if not all, heuristics in normal engineering can be extended to counterparts in the EWT.

The EWT exists at the present time in only a weak sense. In order for it to become stronger, engineers will need to think more broadly about how normal engineering can be extended into areas where it has not typically been applied before.▪

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