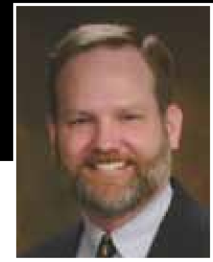
InFocus

The Ladder of Invention

By Jon A. Schmidt, P.E., SECB



Regular readers of this column know that more often than not it addresses some aspect of the relationship between philosophy and engineering. It should thus be no surprise that I am eager to discuss a recent book called *Philosophy and Engineering: Reflections on Practice, Principles and Process*, edited by Diane P. Michelfelder, Natasha McCarthy, and David E. Goldberg, and published by Springer. In fact, I had the privilege of contributing chapter 9 on "Engineering as Willing" based on many of my past writings in this space, including the March 2010 installment of the same name. However, I will not be covering that subject matter this month.

Instead, I want to highlight chapter 27 by M. H. Abolkheir, which has the somewhat unwieldy title, "The Methodological Ladder of Industrialized Inventions: A Description-Based and Explanation-Enhanced Prescriptive Model." The author calls himself "an industrial inventor who is a firm believer in the unique opportunities which are present in applying the abstract tools of philosophy to the examination of industrialised inventions." Substituting "structural engineer" for "industrial inventor" and "engineering practice" for "industrialised inventions" results in a characterization that I would readily apply to myself.

Since groundbreaking inventions are commonly understood to result from "flashes of insight" that seem to come out of nowhere, conventional wisdom says that they cannot be reliably anticipated, let alone intentionally fostered. Abolkheir challenges this assumption by identifying a series of "specific statement-generating phases through which epistemically (predictively) successful industrialised inventions evolve":

1) Epistemic Trigger – The inventor notices an "intriguing causal relation" in the form of either a technological problem (a known and desirable effect for which a cause is sought) or a technological opportunity (a known cause for which a desirable effect is sought).
2) Novel Domain – Most people assign the Epistemic Trigger to a particular area of knowledge and practice by default, but the inventor perceives it as also belonging to a different one.
3) Inventive Hypothesis – The inventor proposes a solution to or exploitation of the Epistemic Trigger that falls within the Novel Domain; i.e., a potential cause of the known and desirable effect, or a potential desirable effect of the known cause.
4) Technological Bundle – The inventor determines a combination of "Confirmed Technological Principles" (CTPs), data-supported instrumental rules and procedures, whose implementation makes the Inventive Hypothesis work.
5) Industrial Design – The inventor refines the Technological Bundle by adding more CTPs to accommodate socio-economic requirements, such as "choice of materials, mass-producibility, cost, safety, user-friendliness, environmental impact, aesthetics, etc."

Each phase terminates with the emergence of a corresponding statement:

1) There is a technological problem E or opportunity C.
2) Problem E or opportunity C belongs to domain X.
3) Within domain X, problem E might be solved by cause C_x, or opportunity C might be exploited to produce effect E_x.
4) To bring about effect E or E_x using cause C_x or C, implement the technological bundle consisting of CTP_1 … CTP_n, where "n" is the number of CTPs necessary to satisfy technical requirements.
5) To achieve an industrial design that incorporates effect E or E_x using cause C_x or C, implement the technological bundle consisting of CTP_1 … CTP_{n+p}, where "p" is the number of CTPs necessary to satisfy socio-economic requirements.

The critical "cognitive leap" typically occurs during the second or third phase – perhaps even as a combination of the two – but considerable creativity is frequently also essential in the later phases. Abolkheir asserts that this overall pattern is consistent regardless of whether the inventor is a single person or a team, whether the phases last for a few moments or many years, and whether the transitions between them occur as the result of systematic effort or happy coincidence. He offers three illustrative examples:

- While working on radar components at Raytheon, Percy Spencer noticed that a chocolate bar in his pocket had melted. He recognized that high-frequency electromagnetic waves could be utilized in the domain of food preparation, leading eventually to the development of the microwave oven.
- While working in the spray-equipment industry, James Dyson noticed that the bag in his vacuum cleaner at home got clogged almost immediately upon use. He recognized that the centrifugal force used to separate powder in one domain could be adapted to separate dirt in another, leading eventually to the development of the cyclonic vacuum cleaner.
- While working in a laboratory, Alexander Fleming noticed that the penicillum mold inhibited the growth of bacteria cultures. He recognized that this could have applications in the domain of pharmaceuticals, leading eventually to the development (by others) of therapeutic antibiotics.

Besides providing a roadmap for successful inventions, Abolkheir's model also explains why some fail to materialize in what might appear to be favorable circumstances. Radar engineers prior to Spencer never took an interest in the heating effect of microwaves (Epistemic Trigger), despite "reports of partially burnt birds at the bottom of radar installations." Vacuum cleaner manufacturers prior to Dyson concentrated on improving filter bags, never widening their focus to include other means of separation (Novel Domain). Although he possessed considerable scientific understanding of antibacterial mold, Fleming himself was never able to formulate a viable treatment (Technological Bundle).

In summary, Abolkheir believes that his "methodological ladder" specifies the conditions that are "individually necessary and jointly sufficient" for carrying out the process of invention from start to finish. Interestingly, he concludes the chapter with a plea that readers "use it with care and employ it only to good ends," evidently recognizing that inventors – like engineers – need practical judgment to guide their applications of technical rationality.▪

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