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THE EVOLUTION OF ENGINEERING: 3D/CAD/CAE/CAM OR CA*X*?

Early in the 20th Century, before the advent of Taylor-based principles for work management, Engineers performed all engineering activities and all engineering-related activities. The Master-Apprentice approach taught each person every activity, which took a great deal of time to do. After the First World War, and into the "Roaring 20s," the demand for goods and services rose rapidly, causing a sharp increase in the demand for engineering talent. The demand for engineers rose so rapidly that the practices of engineering needed to be segmented in order to train people quickly enough to keep pace with what the marketplace required. Within a few years the "technician" and "drafting" functions evolved-out of "engineering." In addition to enabling capacity growth at a quicker rate, this new, segmented work model was more economical since the technician and drafting functions were compensated at lower levels. To keep supply in pace with demand, additional capacity could be put in place faster, at lower average labor cost. Most business functions experienced the impact of Taylor's principles for work management. Engineering was no exception.

Early in the 21st Century, the automation of engineering activities is sufficiently mature to expect a further increase in specialization, and for much the same reasons. In the 20th Century, after Taylor's work principles matured, Engineers still performed both design and analysis. Now "analysis" has evolved into a specialty – in fact into *ten specialties* in each discipline. The early 20th Century segmented engineering into three primary sub-disciplines; in our times engineering has segmented even further, spawning 10-15 separate disciplines within a single specialty area. In the mechanical engineering function, for example, whoever performs finite-element and thermal analysis usually does not perform vibration, tolerance stack-up, kinematic, DFx, reliability, or other analyses typical in design activities. There is a specialist for just about every analysis.

All this specialization is greatly complicating (and slowing) design activities. The question is, *will it remain?* Or, are we seeing a transient condition? Will surfaces, 3D, CAD, finite/thermal, vibration, tolerance stack-up, kinematic, and numerous other specialists remain? Or, will we begin to integrate these specialties into what one might call "CA*x*?"

There is evidence that the trend toward specialization will continue. First, once a Taylor-based work society has defined a specialty it is hard to retract it. This is both a positive and a negative aspect of Taylor-based work cultures. Second, there are limitations on an individual's ability to learn everything that is necessary to be both *wide* and *deep* in any given discipline. For example, it is well documented that the *output of the best engineer in a department is 10x the worst engineer in a department.* These two items alone will prevent current trends from reversing completely, but some consolidation of specialist disciplines is likely – and may be right around the corner.

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Automation typically occurs in "islands." In the long run these islands get tied together. First the islands are "independent," then they become "interfaced," and then they become "integrated." This occurred first in the financial and accounting functions, then in the order processing/distribution and common carrier functions, and then in the manufacturing and production functions. In all cases, both the management systems and the technical systems in each area experienced the same outcome. We are on the cusp of seeing a corresponding development in the engineering and product development functions.

Why do the islands get tied together? Islands of automation enable *effectiveness*. The right result or outcome is achieved with greater certainty and more frequently. *Why is this not enough?* Because *effective* systems must evolve further until they are *efficient* – an equally probable positive result or outcome achieved with less input or cost.

The evolution of technical and management tools for engineering and product development is following the same course as comparable tools in other disciplines. For both technical and management systems, the first wave of automation is nearly complete. Most specialties have numerous suppliers offering competing design automation products to engineers and engineering-related specialists. The first phase of automation is to automate *the task* and this has almost been achieved. On the management side, there are suppliers of process automation, capacity management, project management, product data management, product costing, development costing, time recording, and metrics software to name just a few. Again, the islands are nearly automated.

After twenty-something years of automating the "islands" of product development, it would seem that those civilizations whose work and staffing practices derive from Taylor-based principles are probably at or near peak employment. Just about every specialty has its own, uniquely designed software or automated tool. Suppliers of design automation technology are already moving to integrate their tools across the product design, analysis, drafting, and process design activities. Suppliers of management systems are close to offering comprehensive management solutions for engineering and product development. *What then does the future hold? Probably a painful two decades to move from* ***effective*** *to* ***efficient***.

This article cites several examples from the field of Mechanical Engineering, but I could have provided examples from the Biological, Chemical, Materials, Electrical, Software, *or just about any other* Engineering discipline. The more mature the science of the discipline, the faster it will move from *effective* to *efficient* in a post-automation world. Civil Engineering is the most mature. Mechanical is close behind. Electrical and Software are following quickly. When a science matures, the first thing asked in a supply and demand society is *"how quickly and economically can it be done?"* Effective is no longer good enough – these functions must now become efficient. Becoming effective is glorious. Becoming efficient is usually painful. It appears that two decades of pain are close at hand for large segments of industry.[P D]

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