Core Disciplines for Unifying Engineering Education Revisiting with a focus on Modelling and Simulation

Abd-El-Kader Sahraoui

Core Disciplines for Unifying Engineering Education
Revisiting with a focus on Modelling and Simulation

Abd-El-Kader Sahraoui
LAAS-CNRS and Université de Toulouse
E-mail : sahraoui@laas.fr

Abstract: Engineering education is losing its focus as new engineering courses continue to be created. This is not to say systems engineering education is not considered. It does say each discipline's course tends to be taught in isolation. As a result our students are getting confused by so much diversity with no visible connection. This contributes to the creation of virtual borders between electrical, mechanical and computer engineers and induces artificial barriers for teamwork.

Such improvement can come by making the systems view central to the educational process.. This includes giving students experience in working in interdisciplinary teams. Our proposal is that systems engineering core courses be made the nucleus around which all engineering disciplines are centered. Furthermore it is proposed curriculum be modified to include case studies in core disciplines that can taught in many departments: modeling and simulation, requirements engineering, and validation and verification. In this way all students would be introduced to the basic elements of the system engineering conceptual framework. Process methodology would also be addressed.

Keywords : engineering education, systems engineering, engineering product, financial, risk management and analysis

Introduction

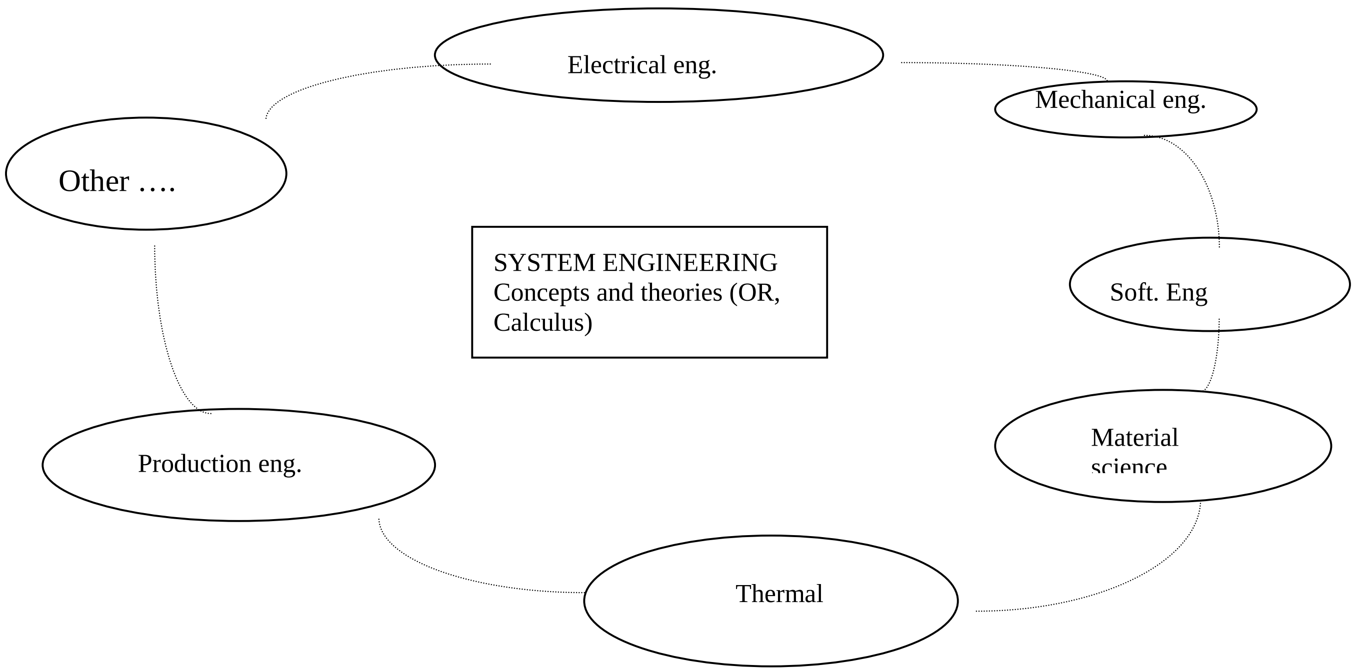
Mathematics is an essential tool for most scientific disciplines. It is also an excellent way to teach abstract reasoning to engineering students. French engineering education follows this paradigm. Entry to the best engineering schools (*Grandes Ecoles* : great schools) is based on selection at the A-level of the best college students in mathematics. After two years of training in a mathematics oriented education, they are again selected to enter the engineering school of their choice.

This system is currently criticized by many eminent French scientists, most notably messieurs Gilles de Genes and Georges Charpak --recent Nobel prize winners in physics/chemistry. While they acknowledge the importance of mathematics, they make the case it is not essential for technical disciplines which rely heavily on inductive reasoning, i.e., system engineering. Thus we have the situation that while system engineering is broadly espoused by French industry and government leaders, it has yet to be translated into the academic environment. This, in part, is due to a lack of universally accepted definitions and principals.

I believe creating a set of systems engineering core courses for inclusion in all engineering curricula would resolve many of the concerns raised by messieurs de Genes, Charpak. and others.

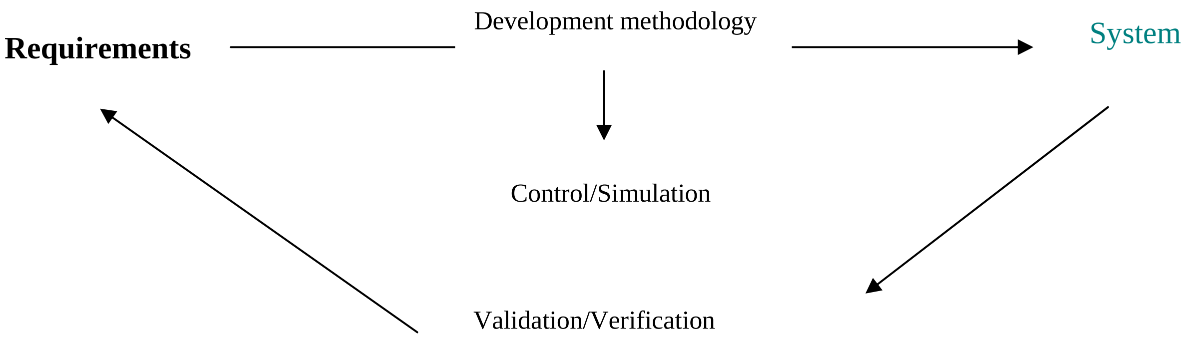
Requirements for SE Education: Concept Unification

Based on my experience teaching in universities and industry, SE should be taught as both a discipline and a set of core courses to provide a means for unifying the other engineering disciplines.



We may ask what are the essential or core SE concepts? Are they only useful to systems engineers.? Experience suggests all engineers can improve their skill set by being taught system thinking.

As illustrated in the following figure, we have a development process that leads to the development of a system meeting a pre-determined set of requirements. Simulation is used to evaluate system behavior. Verification and Validation close the loop back to requirement to establish how well system performance meets customer objectives.



Concepts are mapped into core courses. These core courses should contain, in our view, most concepts basic to SE (for example, in methods teaching, one finds structuring and abstraction/refinement concepts and corresponding techniques).

From observation it is clear one course must be structured to teach students system engineering concepts. This course might be named: "A Basic introduction for engineering a System.

Such an approach will teach students how to:

- -Avoid redundancy and consistency problems and
- -Convey common knowledge to students so they will, after graduation, know how to work together in engineering a system.

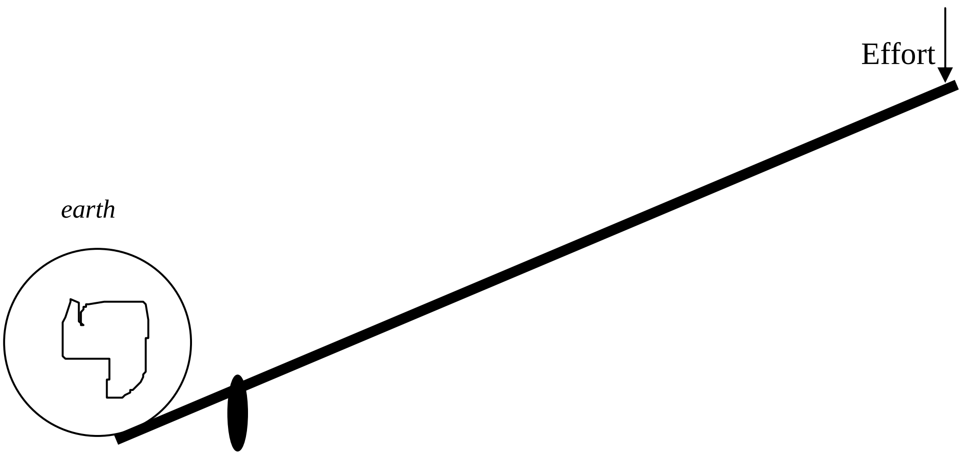
It is beyond the scope of this article to detail concepts contained within each core course. The objective is to define a systems engineering course of instruction using core modules as the unifying discipline for engineering education.

Experience in Teaching Systems Engineering

Methodology issue

The value of process methodology (a logical progression of activities)is often not recognized by many engineering educators. Currently both the systems and software engineering discipline recognize the importance of having a well understood design process. These manifested themselves as SD (structured Design Method) in the seventies and analysis methods as

SADT (Structural Analysis and Design Technique) in 1977. The value of a method is illustrated in Archimedes statement *"Give me a place to stand, and I will move the world."*



The method corresponds to the application of the mechanical principle of the lever. The tool consists of the support and lever. The longer the lever, more powerful the method. However, the technique for pressing on the lever corresponds to the method used. With a good teaching method concepts such as abstraction, hierarchy, and refined analysis were easily mastered by students. Similar teaching success have been achieved at an engineering school specializing in industrial engineering. A typical problem set was to design a gear box using an object paradigm. Passing software messages should have it a counterpart in the gear box. (the linear speed transmission between two gear wheels).

Requirements engineering: Why a requirements step is essential to all technical disciplines.

While all computer science majors are taught the criticality of understanding requirements, many other majors, particularly those where the design process is prominent, do not impress upon students the need to get a good grasp of requirements before starting the design.
One technique used (repeatable) through sixteen short term projects per year at the technology institute IUT-B (Université de Toulouse le Mirail) proved successful in teaching students the value of requirements. First year students were assigned the task of acquire course requirements by contacting lecturers. Part of the assignment was to write these requirements in a specific format. When it came time for the requirements engineering lecture, the experience helped in raising student interest and attentiveness.

Validation and Verification (V&V) processes

Most students consider V&V a waste of time. Getting students to understand why the V&V process needs to be embedded within their work has been a major undertaking. Equally daunting has been the task of convincing them the V&V process is needed for both hardware and software. Moreover, the same principles apply for verifying software in computer science or verifying mechanical structure in mechanical systems. Fault tolerance, system reliability, and associated concepts are basic elements in this core module.

To teach this to students, we have experimented with illustrating concepts with simple everyday life examples. For example, getting to a specific place from a requirement based on a map or why negotiation difficulties are often the result of either consistency problems or semantic problems related to bad syntax/terminology, etc ..

Modeling and simulation

Defining Requirements is a modeling process.

The requirement process is used to produce an abstract model of the system. Simulation is a means for partially verifying requirements and learning about system behavior. Simulation is also used in many requirement development schemas in order to have an executable specification to avoid having to build a prototype in the initial project phase.

Personal experiments, starting in 1988, with teaching modeling and simulation to all engineering students have shown that most students have little trouble with the concept of working across discipline to produce systems models. They learn a perspective impossible to teach when modeling is taught in discipline specific modeling courses. Also clear was that their experience taught them the value of working across discipline to achieve a common objective.

Modeling and simulation skills are two core competencies of computational science and thus should be a central part of any curriculum. While there is a well-founded theory of simulation algorithms today the teaching of modeling skills bears some intrinsic problems. The reason is that modeling is still partly an art and partly a science. As an important consequence for university education the didactic concepts for teaching modeling must be quite different from those for teaching simulation algorithms.

The revival of modeling and simulation as an important tool for such things as the design of numerical systems underlines the importance of teaching students to have a systems view. There is not a problem with each engineering discipline teaching modeling separately. The problem lies with first teaching students system modeling. This teaches students why the electrical or mechanical systems they are modeling must be able in interfacing with the other systems elements. If students first course were one in systems modeling, much of the time spent by the various discipline teaching modeling fundamentals could be eliminated and this increase the time spent on teaching discipline specific modeling techniques. .

Lacking a core set of systems engineering courses, it is no wonder many of our students graduate with an incomplete understanding of how to engineer a system.

Hands on modeling and model validation

The modeling phase is a nota simple phase however students must have hands on by themselves on developing models; such experience can be carried out in labs with physical models as thermal, hydraulics, mechanical ; model validation through comparing output from sensors and from simulated models; hands on tuning such models.

Abstract models , financial models, social models
It was noticed since a decade a rush of engineering students to graduate studies not related to the specialties of their department or engineering schools and mainly to economics financial, sustainable development. These new specialties integrate the quantitative aspects and hence were open to engineering student where most of them were planning having a career in developing industrial products or working maintenance in industrial factories.

On financial modeling, building models of bond and stock prices, these two theories lead in different directions: Black–Scholes arbitrage pricing of options and other derivative securities on the one hand, and Markowitz portfolio optimisation and the Capital Asset Pricing Model on the other hand. Models based on the principle of no arbitrage can also be developed to study interest rates and their term structure. These are three major areas of models of finance, all having an enormous impact on the way modern financial markets operate. This textbook presents them at a level aimed at second or third year undergraduate students, not only of mathematics but also, for example, business management, finance or economics. There are available libraries in Matlab ou Mapple to handle such partial equations and see effects of parameters on models and sensitivity factors.

Complex systems modeling

Concerning model global systems where natural systems, social team is still an active area of research but still can be open for teaching such potential models as students grasp the quantitative nature of such models and open new perspectives for electrical engineer working with a biologist. In such respect some universities like UC at Berkeley have been pioneer in opening an undergraduate course and department on bioengineering.

Conclusions

Most European countries expect students to complete a five year course of study to earn a Bachelor of Engineering degree. The first two years are concentrated on taking foundation courses common to all of engineering. Specialized courses specific to their chosen field of study are taken in the years three through five.

Four core SE courses have been identified as being valuable to all engineers. Personal experience suggest that adding one course per year in the second through fifth year would be relatively easy and would produce much capable graduates.

The modeling course must be the focus point in improving engineering education for a smooth evolution as the systems view was in late 60’s

References

G. Genes : Les objets mous. Editions Odile Jacob

G. Charpack : l'ingénieur ingénieux, préface , Editions Odile Jacob.

S. Weiss : Legitimacy for system engineering in Academia. Talk given at the INCOSE academic forum, MIT, , Cambridge, june 96.

L. A. Macauley : Requirement engineering. Springer Verlag, Applied computing series, 1996

A.E.K Sahraoui : Modeling and simulation, issues and perspectives in education. IMACS international symposium on system modeling and simulation., Cetrato, Italy, Sept 88, p228-232.

A.E.K Sahraoui : systems engineering education, Insight Journal, Incose, Vol2, 2001

M. Mano : logic circuits, Prentice hall.

W. Wiechert : Teaching mathematical modeling: Art or science?; ICCS 2002 : international conference on computational science

Biography : Dr Abd-El-Kader Sahraoui is professor at IUT-B institute at Toulouse University and research fellow at LAAS-CNRS Toulouse.