CLAIU-EU Conference

The Formation of Engineers – International Models

Rome – 11th & 12th February 2011

Conception Engineers *versus* Application Engineers : the Views of Industry

by Marc GOOSSENS, Ir., M.Ph.Sc., Director of SEII (*European Society for Engineers and Industrialists*) – seiimg@abuco-consult.com

Abstract

What exactly means industry when they say that engineers, by and large, should have a more practical mindset ? Is it linked with the existence of both conception-oriented engineers, who have a more theoretical approach of their work, and application-oriented engineers, with a more practical approach ? Could we really compare them, as their work is different ? Moreover, there is no clear-cut divide between them. My presentation will then be a trip in the world of words, of symbols, and of cognitive models, ending up – I hope – with a clearer grasp of where that reproach, addressed by industry to engineers, is coming from. It will appear, in particular, that engineers should know how their brain is working and so have less faith in their cognitive models, a solution that would also preserve their creativity and innovation capabilities. If it is up to Engineering Education to provide for that, it is up to industry, on the contrary, to find a solution to the problem of communication between both types of engineers.

0. Introduction

I am here on behalf of the European Society for Engineers and Industrialists (**SEII**) in order to present the views of industry on one of the topics of this conference.

SEII, as many of you already know, is a non-profit-making association, set up seven years ago, with the aim of providing European engineers and Industrialists with leading-edge information and reflections, mainly through lectures and conferences.

We also are involved in some programmes initiated and/or supported by the European Commission, for instance in partnering in **EUGENE** (EUropean and Global ENgineering Education), a SOCRATES-ERASMUS funded Academic Network, and in taking part in the European University-Business Forum.

I whish to address a warm " thank you " to Denis Mc GRATH, presently Past-President of CLAIU-EU, for having invited SEII to contribute a second time to their conference, since, one year ago in Brussels, I explained what the Engineering Skills Needs of Industry were.

Today, I am supposed to present – not necessarily to defend – the views of industry on the positive and negative aspects of conception-oriented engineers, namely engineers who have a rather theoretical approach of their work, as compared with the application-oriented engineers, with a more practical approach.

After having shortly – I shall explain why – presented the "views" of industry, I shall make a rather long detour in our world, the world of mankind, which has developed on the base of symbolic representations, and then explain what the consequences are for both Engineers' work and Engineering Education.

1. The views of industry

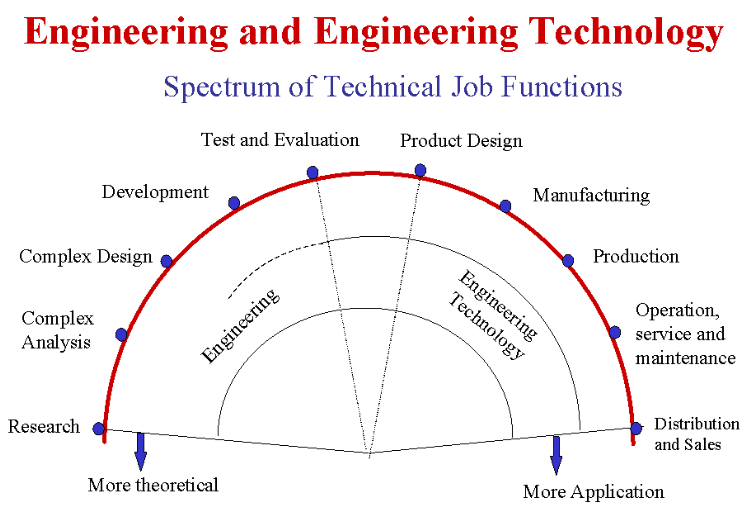
I said « *I am supposed* » because I soon realized, through my contacts with industry and industrial associations on that subject, that, though they acknowledge the fact there is such a dichotomy, they are in fact calling for both types of engineers – to a different extent, depending on their field of activity – and they cannot really compare them, as their work is different. Moreover, there is no clear-cut divide between them.

It is also difficult to have a general and argued point of view of industry on that subject, because it seems that engineers do not form anymore the main focus of their concern. For instance, in the 2008 edition of IBM's biannual Global CEO Study, " *The Enterprise of the Future* ", which spreads over some fifty pages, the word " Engineer " does not even appear once ! But such words as " Manager " or " Leader " appear on nearly every page !

Sign of the times : engineers, who have been at the base of the industrial revolution, have now become nothing more than a special type of employees.

Nevertheless, by and large, industrial companies expect from their engineers to have a more practical look at their work. In a position paper dated from last October the 10th about their expectations on European cooperation in VET (Vocational Education and Training), BUSINESSEUROPE acknowledge the importance of such skills as adaptability, entrepreneurship, creativity and innovation capacity, but at the same time they emphasize the fact that employers do not reward qualifications, but **performance**, and regret the recent trend towards making VET more theoretical, with reduced practical training as consequence. Anyway, the exact meaning of this statement is not very explicit.

Actually, what do we mean exactly when we say that an engineer is " ***theoretical*** " and another one " ***practical*** " ? Though one can place approximately some engineering functions on a scale going from " very theoretical " to " very practical ", as schematized on the following diagram, it is however impossible to assign, to each of those types of engineers, a precise enough quotation on a graduated scale.



Here are some differences between conception-oriented and application-oriented engineers, as given to me by a manager of SOLVAY, a large Belgian corporate :

Conception-oriented engineers	**Application-oriented engineers**
*Are capable of and accustomed to abstract thinking and **problem solving**, by using their scientific and technical background.* *Tend to have also **"soft" skills**, including communication, interpersonal, cross-cultural and team-building skills.* *Are willing to lead and manage **innovation**.* *Need **only a global direction** to establish a strategy and an action plan.* *Are better suited to **build a knowledge economy**.*	*Have a solid technical training ("hard" skills).* *Feel less comfortable in using their technical training to solve larger problems or to deal with novel situations.* *Generally possess weaker "soft" skills.* *Are frequently assigned to repetitive tasks, for which they perform well.* *Need clear directives and then carry out the requested actions in details.*

It is obvious that conception-oriented engineers and application-oriented engineers have quite different skills and capabilities, but also that both types of engineers are appreciated and searched for by industry.

So, I was faced with a big difficulty, particularly as, in the next presentation, Professor Sabastião FEYO de AZEVEDO is going to consider both the theoretical and practical approaches in engineering education and I did not want to trespass on his area of responsibility in this conference.

2. <u>We live in a world of symbols</u>

In order to meet that challenge, I invite you to accompany me on a trip in the world of words, of symbols and of cognitive models, a trip during which we shall meet different possible explanations of the problem in question, and which – I hope –, by a convergence effect, will end up with a clearer grasp of what industry is expecting from engineers in that perspective and with some suggestions as to what could be done to improve the situation.

2.a. Words are symbols

Formation, models, engineer, practical, theoretical, … During this conference, we shall be using, essentially, one kind of tools : words ! Words play a key role in thinking, communicating, learning, and so on.

A particular attention must therefore be turned to their meaning. Nouns and adjectives can be divided into two categories, either polythetic words or non polythetic words, from a term first introduced by the British anthropologist Rodney NEEDHAM :

- Non polythetic words are mainly nouns, the clear-cut definition of which leaves little room for a doubt, when an object has to be said responding or not to that definition : *a microphone, a chair, a banana, a tulip, a cow, an elephant, the sun, and so on …*
- Polythetic words, on the contrary, do not have a clear-cut definition and there are many " objects " about which one can argue whether they respond or not to a given definition : *yellow, big, satisfying, game, cause, reason, mobility, attitude, science, and so on …* There are many more polythetic words than non polythetic words.

Most words that form the subject of this presentation are polythetic. But, because they are accustomed to precise definitions, engineers usually do not feel comfortable with polythetic words and tend to transform them into non polythetic representations !

Let us look, for instance, at the many definitions of what an engineer is :

- An Engineer is someone whose activity consists in solving concrete and often complex technological problems, which arise when conceiving, implementing or producing products, systems or services, a skill that results from a set of scientific, technical, economic, social and human knowledge (CTI – Commission des Titres d'Ingénieurs – France).
- An Engineer is someone who combines a rational attitude, a strong analysis ability, a suggestive force, a methodological approach for solving problems, and self-confidence in carrying on his or her duties (CGTI – Conseil Général des Technologies de l'Information – France).
- An Engineer is someone who practises a profession in which a knowledge of the mathematical and natural sciences gained by study, experience and practice is applied with judgement to develop ways to utilize economically the materials and forces of nature for the benefit of mankind (ABET – Accreditation Board for Engineering & Technology – USA).
- An Engineer is someone who designs devices, components, subsystems and systems and who, in order to create a successful design in the sense that it leads directly or indirectly to an

improvement in our quality of life, must work within the constraints provided by technical, economic, business, political, social and ethical issues (NAE – National Academy of Engineering – USA).

In those definitions, which indisputably present a family likeness, practically all the words are polythetic and it is impossible to have a clear-cut definition of an engineer.

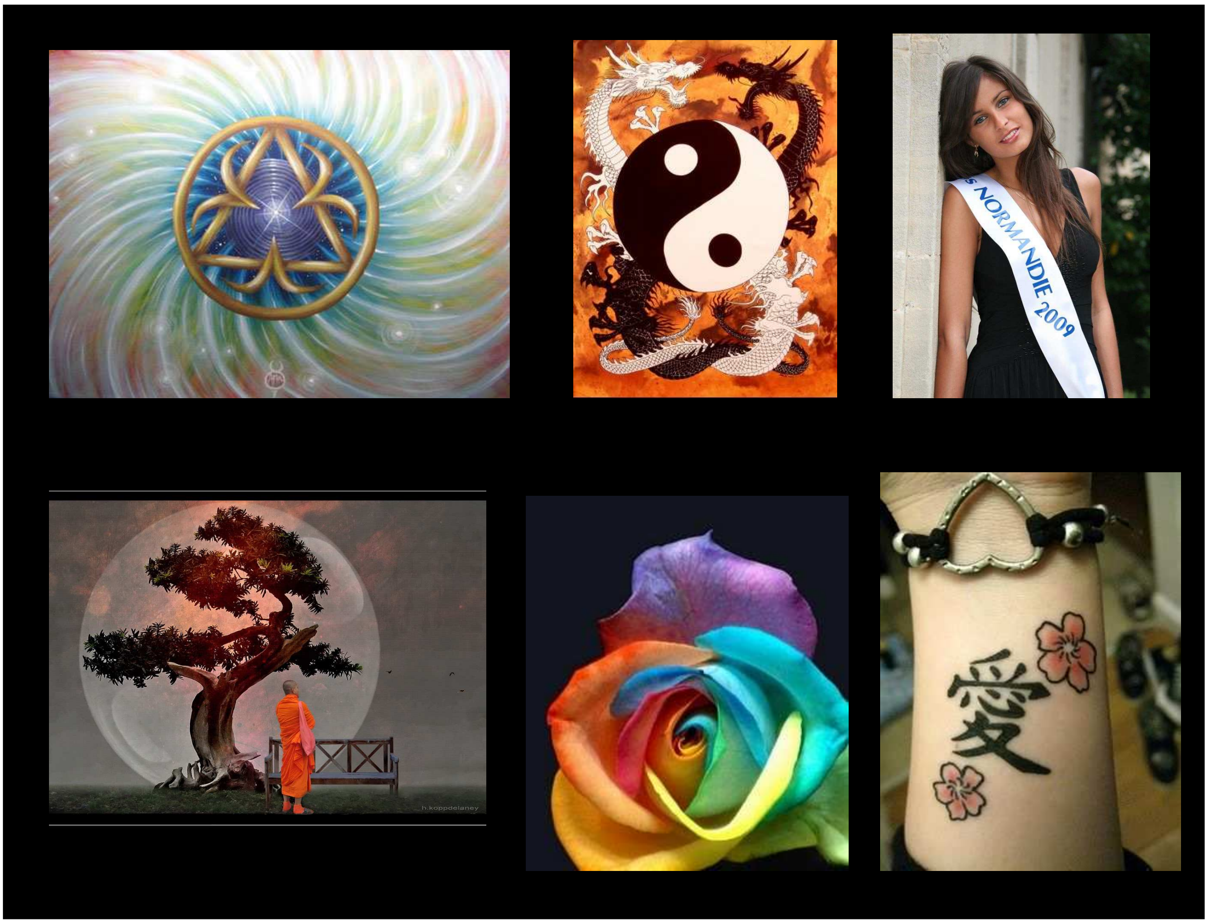
Let us now consider the various types of engineers, most of which are listed in the table hereafter, according either to their speciality or to their function :

According to their speciality **:**	***According to their function*** **:**
Transportation engineer	Research & Development engineer
Construction engineer	Process control engineer
Agricultural engineer	Design engineer
Mechanical engineer	Project engineer
Electrical engineer	Methods engineer
Electronics engineer	Production engineer
Electro-technical engineer	Systems engineer
Chemical engineer	Product engineer
Aeronautical engineer	Quality-control engineer
Naval engineer	Application engineer
Bioengineer	Business engineer
Data-processing engineer	Customer engineer
Network engineer	Sales engineer
Robotics engineer	Consulting engineer
Etc …	Etc …

We must admit that their definition, and above all their delimitation, are quite imprecise !

We have to remember that words are symbols. Unlike any other known life form, we, human beings, have evolved a capacity to create and manipulate symbols and to compare them with the “ outside world ” (that is to say everything external to human body). This capacity allowed the transference of symbols from the mind to symbols outside the body and the mind. By creating unique vocal patterns or artful scratching designs on stone, wood or papyrus, somehow we learned how to compare the sounds and designs to thoughts in the mind. By learning and teaching how to remember the symbols through the use of a common code, an alphabet, we gained the ability to communicate our ideas through space and time.

So, a symbol is a mediator between our mind and the outside world. It is a meta-language.



There are many sorts of symbols : words, drawings, paintings, tattoos, objects, and even individuals ; they can be real or imaginary (as the rainbow rose in “Alice in Wonderland”), simple or complex, single or grouped.

Everything we perceive from the outside world through our five senses is transformed into a symbolic network of activated neurones ; and anything that we say or do is activated by a subsequent arrangement of symbolic networks of neurones, that have been more or less accurately memorized and recalled ; furthermore, that activation can be partially or even totally blocked or distorted by the interference of our emotions. So, symbols are key elements of all human activities, including science and technology.

Coming back to words, let us look at a simple sentence as : « ***This chimpanzee is eating a banana*** », which is of course perfectly correct.

If we change the order of the words at random, we may have something as : « ***Eating this is banana a chimpanzee*** », which is theoretically wrong because it does not respect the grammatical rules.

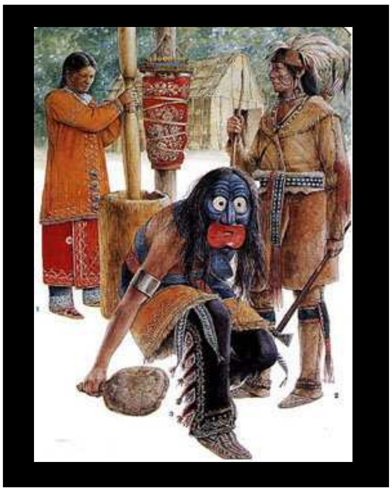
But, if I simply replace the word "***chimpanzee***" by a word as "***chair***" or "***rock***", we get a sentence that is still theoretically correct, as it respects the grammatical rules, but that is "practically" wrong, because it has no meaning in the real world, as everybody knows – or should know – that neither a chair nor a rock can eat a banana.

So, we have here a first distinction between " theoretical " and " practical " :

- " ***Theoretical*** " refers to the rules governing the use of symbols and, by extension, of our cognitive models ;
- " ***Practical*** " refers to the appropriateness of a set of symbols or cognitive models to the reality of a larger set with which it is, or will have to be, connected.

In the second case, this appropriateness can result from personal experience, namely a direct contact with the related reality, or from an indirect contact with that reality through another person. This introduces a new parameter that we shall have to take into consideration : the quality of the communication between those two persons.

2.b. <u>The symbolism of the mask</u>

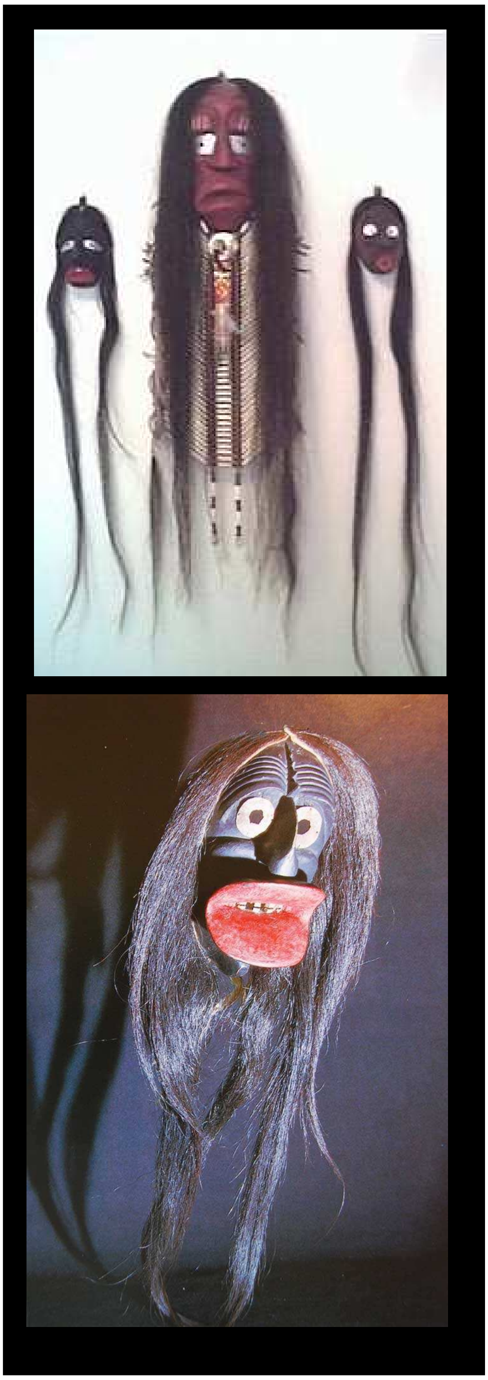


With that aim in mind, I shall continue my journey in the world of symbols through briefly considering the symbolism of the mask.

As any of us, the Iroquois Indians were suffering from many diseases and various pains, not to mention the wounds that were inflicted on them by animals and enemies. When it was the case, they were calling for a member of the False Face Society, a brotherhood of medicine men that was represented in all the villages.

Its members had the particularity that they were all wearing a mask that was concealing their identity.

But, this was not the main object of the mask. The Iroquois Indian who was wearing it had stopped being a normal member of the tribe and had been transformed into a medicine man, a powerful healer, a sorcerer. The main object of the mask was not to prevent people to identify him, but on the contrary to allow them to **recognize him** as a shaman.



Becoming a member of the False Face Society was not as easy as that.

- **First**, the candidate must have been called, in a dream, by a spirit who explained to him how to manufacture the false face and taught him the ritual gestures and songs, which together will give him the power of a medicine man.
- **Second**, he must go and meet the oldest members of the False Face Society, in order to explain his dream.
- **Third**, if he has proved to possess a true knowledge, he receives two small representations of a mask.
- **Fourth**, he must manufacture his definite mask, following the indications that he received in his dream, by carving it in the trunk of a good tree.
- And **fifth**, when his mask is finished and correctly made, he receives the right to practise as a medicine man.

There is a **striking resemblance** between those five steps and the five steps that a student in engineering has – or should have – to climb to become a professional engineer :

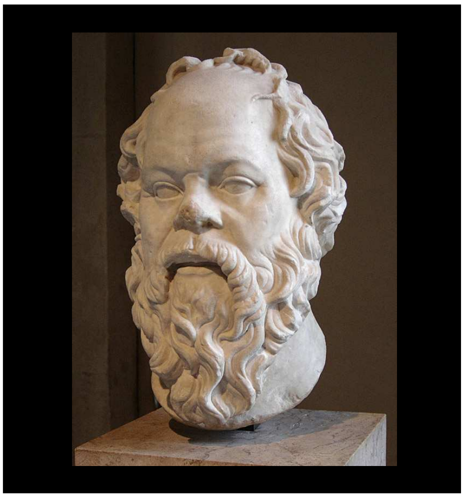
Becoming a member of the False Face Society	Becoming a Professional Engineer
1° Learning "how to do" in a dream.	***1° Theoretical learning at school.***
2° Explaining their dream before the Elders of the Society.	***2° Proving theoretical knowledge before one's Professors.***
3° Receiving two little masks.	***3° Receiving one's degree or diploma.***
4° Manufacturing the mask.	***4° Gaining practical know-how.***
5° Having the right to practise as a medicine man.	***5° Being recognized as a qualified professional engineer.***

No, our western civilization has not invented everything : some science and technology, and that is all !

But we can go further than that. In English, as in other European languages, we generally say of a man or a woman that he or she is a " person ".

This word derives from the Latin word " ***persona*** ", which designed the mask that the stage actors were always wearing to symbolize their role.

We all wear a mask, an immaterial mask, in order to better attract the consideration linked with our position and function in the society. **Just as actors learn their part in order to play their role on the stage, symbolized by a mask, we learn at school in order to play our role in society, symbolized by a qualification**.



We are even wearing a mask when we look at ourselves in a mirror, because we identify ourselves with our role !

When **SOCRATES** said " Γνϖθι σαυτον " (*Gnôthi sauton* = " ***Know thyself and thou shalt know the universe*** "), wasn't he meaning : " *Look behind your mask !* ".

I cannot refrain from reproducing here a striking poem of the English novelist and poet **David Herbert LAWRENCE** (1885 – 1930), who prematurely died from tuberculosis :

<u>Know Thyself and that Thou art Mortal</u>

If you want to know yourself,
You've got to keep up with yourself.
Your self moves on, and is not today what it was yesterday ;
And you've got to run, to keep up with it.

But sometimes we run ahead too fast,
Running after a figment of ourselves.
And that's what we've done today.

We think we're such clever little johnnies,
With our sharp little eyes and our high-power machines,
Which get us ahead so much faster than our feet could ever carry us.

When, alas, it's only part of our clever little self that gets ahead !
Something is left behind, lost and howling, and we know it.

Ah, clever Odysseus who outwitted the Cyclop
And blinded him in his one big eye,
Put out a light of consciousness and left a blinded brute.

Clever little ants in spectacles, we are,
Performing our antics.

But, what we also are, and we need to know it,
Is blinded brutes of Cyclops, with our cyclopean eye put out.

And we still bleed, and we grope and roar,
For spectacles and bulging clever ant-eyes are no good to the cyclop :
He wants his one great wondering eye, the eye of the cavern and the portent.

As little social ants perhaps we function all right.
But oh, our human lives, the lunging blind cyclops we are !
Hitting ourselves against unseen rock, crashing our head against the roof
Of the ancient cave, smashing into one another,
Tearing each other's feelings, trampling each other's tenderest emotions to mud
And never knowing what we are doing, roaring blind with pain and dismay.

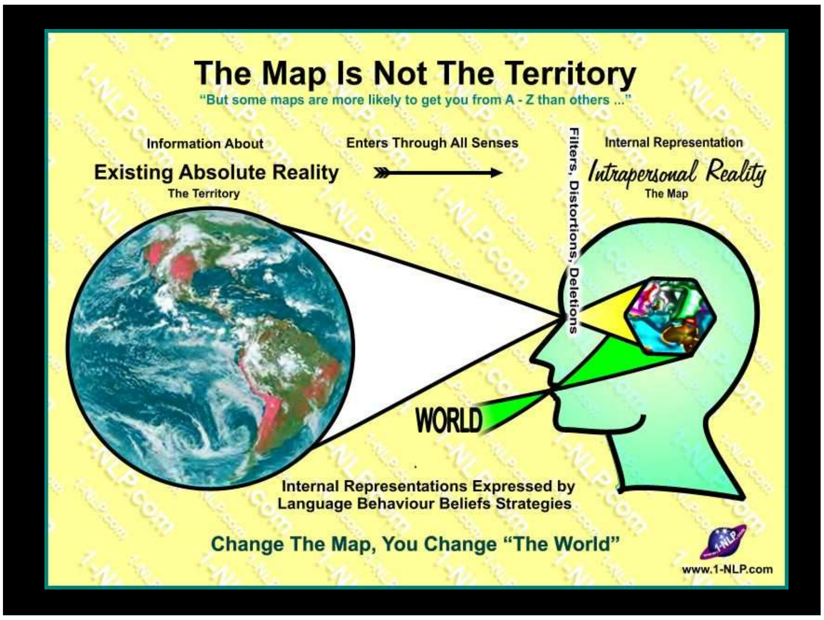
Ah, Cyclops, the little ant-men can never enlighten you
With their bulging policeman-lamp eyes.
You need your own great wondering eye that flashes with instinct in the cavern
And gleams on the world with the warm dark vision of intuition !

Even our most brilliant young intellectuals
Are also poor blind cyclops, moaning
With all the hurt to their instinctive and emotional selves,
And grieving with puppy-like blind crying
Over their mutilated cyclopean eye.

So, we have seen up to now that being “ practical ” means « ***developing sets of cognitive models that are appropriate to the reality*** » and that, in order to do so, we depend in many cases on the communication with other people, communication that is made more difficult because we are all wearing different masks, with which we identify ourselves.

2.c. <u>The map is not the territory</u>

The problem is worse because, when we are thinking or doing something, we are not directly geared to reality, but only to the models of the reality that we have built in our mind, a sort of map of the world, and we can do nothing else but confuse the symbols – a model is made of symbols – with the things they are supposed to represent. In 1936 already, **Alfred KORZYBSKI**, a Polish-born American Engineer, who specialized in human sciences and created the general semantics, said that : “ ***The map is not the territory*** ” !



The Belgian surrealist **René MAGRITTE** illustrated that concept of “ perception always intercedes between reality and ourselves ” in a number of paintings, including a famous work entitled “ *The Treachery of Images* ”, which consists of a drawing of a pipe with the caption : “ ***This is not a pipe*** ” .

Confusing the map with the territory, the theoretical model with its practical application, is probably more common among those engineers, whom I put together under the polythetic word of “ theoretical engineers ”, because they are operating farther from reality than the so-called “ practical engineers ”.

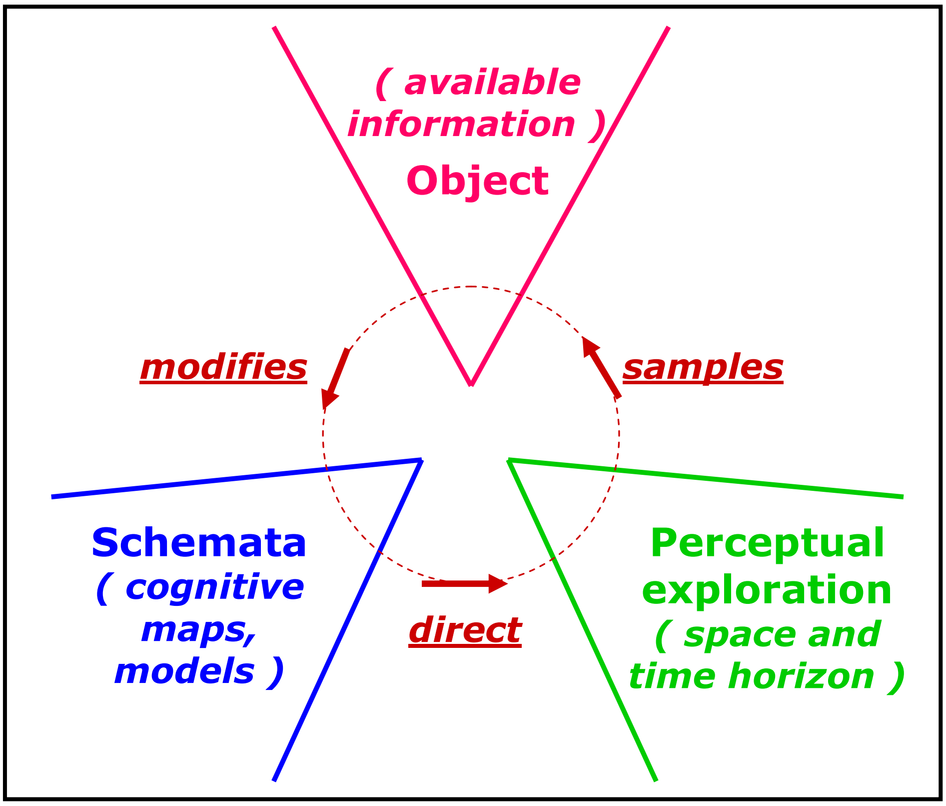
David PYE (1914 – 1993), who was Professor of Furniture Design at the Royal College of Art, makes a distinction between the “ workmanship of risk ” and the “ workmanship of certainty ”, and argues that only direct practical involvement can take on the risks of variables and inconsistencies. Design, he says, deals with certainties : “ ***In a designer’s drawing, all joints fit perfectly*** ”.

A map cannot be as precise and complete as the territory, otherwise it would not be a map, but the territory itself ! If I add that we don’t have access, individually, to the whole world and must rely on other people for most of our knowledge ; that it seems that our brain finds it quite difficult to transform polythetic words into cognitive models, as the first are blurred and the second have to be precise (in the form of a network of neurones) ; and that the use of our cognitive models is partially governed by our emotions and beliefs, you will admit with me that our comprehension of reality is both quite limited and distorted.

2.d. <u>NEISSER’s perceptual cycle</u>

We have to pursue our quest, not for the Holy Grail, but for an explanation of how our mind builds those cognitive models, because, without such an explanation, we could not find an effective way of managing that difference between the approach of theoretical engineers and the approach of practical engineers.

I shall refer to the framework developed by the German-born American cognitive psychologist **Ulrich NEISSER**, a framework which pretends to explain the learning process itself and retains a considerable degree of consensual support among psychologists, anthropologists and noted management academics.



Generally referred to as NEISSER's perceptual cycle, it consists of a triangular relationship between the models that we have in our brain – which NEISSER calls the schemata –, the exploration that we lead in a part of the world around us in order to find a satisfaction to our needs, and the available information given by the objects selected in our environment.

This cycle represents the elementary unit of the learning process and, as it is the case with the cycle between the hen and the egg, it has no beginning and no end. Let us start, for instance, with the cognitive maps that we have in our mind at one moment, and which direct our perceptual exploration towards a certain zone of the territory around us, where we sample an "object" more or less complex, concrete or symbolic, which provides our mind with some new information, which in turn will modify or expand our cognitive map. And we can then begin a new cycle.

Going round the cycle takes some time, an extremely short time, but it is not instantaneous, and so the succession of cycles takes the form of a helical path, with billions of whorls in the interval that separates our death from our birth. This is maybe the origin of our psychological perception of passing time.

The important point of this process is the continuous dialogue between our cognitive maps and the reality of the external territory, and this is typical of human beings. Many animals can learn by themselves but, when they do, it is by a " cut and try " method, doing at random first one thing and another thing, and then preserving the things that happen to succeed.

In human beings, the succession of perceptual cycles led them progressively to understand that they could act deliberately on the external territory in order to modify it. And, when passing from learning to manufacturing, they preserved the same process : first having in their mind a model of what they wanted to make ; second, searching around them the necessary material ; and third, when beginning to act on the material, understanding that the initial model was not adapted to the reality and has to be replaced by a new one, giving way to a progressive improvement.

So did the Palaeolithic men, when carving out their flint tools, so did the first farmers in Egypt and in China when building their irrigation systems, so have done thousands of craftsmen for many centuries, so did Marshal VAUBAN, Military Engineer, when fortifying the borders of France.

Then, the Industrial Revolution, with Frederick Winslow TAYLOR and his principle of the division of labour, changed the situation. At the beginning, engineers were not really concerned by this phenomenon, but later, particularly after the Second World War and the explosion of engineering sciences, they also got affected.

3. <u>Consequences for Engineers' work</u>

I do not intend to question the principle of division of labour for engineers : a single man could not replace the whole orchestra ! But our mind has not adapted to the new paradigm. For thousands of generations, men have been thinking that, when they were transforming some model they had in their mind into a material object, they were in some sort passing from the map to the territory.

But, when a design-engineer transforms the model he has in his mind into a series of drawings and texts on a sheet of paper or on the screen of his computer, his is still working on the map, not on the territory : drawings and words are symbols, not reality. That is why, sometimes, his work is more or less disconnected with reality.

An engineering project can be seen as the course of a river, with theoretical engineers working at the source of the river, and practical engineers working at the mouth. Increasing the number and quality of engineers working at the mouth, at the cost of those working at the source, is not going to increase the discharge of the river.

But, an analogy is also a symbolic representation and can be misleading, because here, in the case of an engineering project, there is also an upstream flow of information, for which the source is the mouth and vice versa. And this makes things more difficult.

So – though this is of course a simplified image – we might say that there are two NEISSER's perceptual cycles that have to "work" in harmony and with a good efficiency : the perceptual cycle of the theoretical engineer and the perceptual cycle of the practical engineer : one immediately sees that the first one, entirely "working" on the map, can only get some cognition of the territory only through the "channel" of second one.

Obviously, the full perceptual cycle of the couple formed by a theoretical engineer and a practical engineer is much longer that the cycle of an application-oriented engineer alone, and this increases the volume of possible distortions through modelizing, communicating and de-modelizing.

All this is, for me, the main reason why industry consider that many conception-oriented engineers are too theoretical (or not enough practical, what amounts to the same thing). Now, the question is : " ***What can Engineering Education do about that ?*** ".

4. Consequences for Engineering Education

I do not pretend to outline a whole pattern of what Engineering Education should do : I do not have the ability for that. I shall just point out what I regard as a lack or a danger in the present and future Engineering Education.

4.a. How our brain – that wonderful little machine – is working

Engineers know how machines work, from the smallest, such as an electronic chip, to the largest, such as the Large Hadrons Collector at the CERN in Geneva, depending on their speciality.

But it is altogether amazing and deplorable to see that they do not know how works that marvellous little machine they use every day : their brain !

I do not speak only of what I just said in this presentation about symbols, cognitive models and perceptual cycles, but also of the interference between our two mental modes, the automatic and the prefrontal modes, which is or can be at the origin of stress, of resistance to change, of a lack of flexibility, of leadership, of our system of values, of our self-confidence and of our motivation.

If engineers knew that their brain does not work in a real world, but in a world of cognitive models that are only imperfect representations of a reality that lies beyond their understanding, if they knew that the more theoretical or abstract is the model, the less appropriate it can be when applied in the reality, they would probably better look after the practical application of their models. Reality is masked – hence the symbolism of the mask – and we can only work on the masks, not on reality itself.

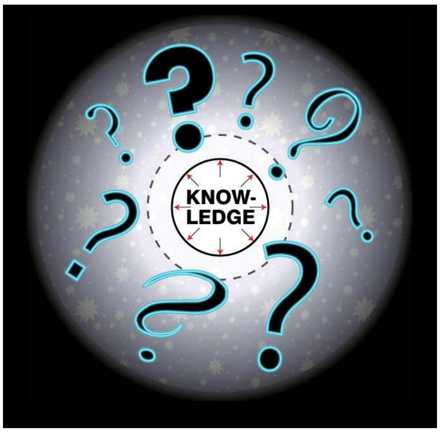
4.b. We depend on cognitive models

We need cognitive models, because it is through them that our brain has been producing and will go on producing all what forms our civilization, and, as evolution tends to more complexity, we shall have to work with more and more complex models.

But models are dangerous, particularly if we confuse them with reality : they induce craze, fashions and idolatry ; you can easily see the symptoms : when someone proposes a new model, it spreads as an epidemic, slowly first, then faster and faster, and, at the end, if you are not infected, you are considered as completely abnormal !

4.c. <u>The learning process</u>

I am now going to consider the learning process, for the processes that we apply in our schools and universities are just models, necessary but dangerous as I just said, and formation models are precisely the subject of today's presentations.

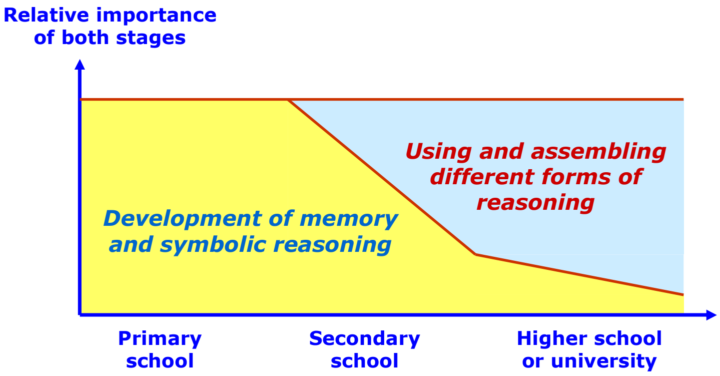


I have a question first : « ***Why do we have to learn ?*** ». The answer seems obvious : « ***In order to get knowledge*** ». Yes, but : « ***What is knowledge ?*** ».

I would say that knowledge is a set of models that are supposed to depict the masked reality and to provide us with tools for acting, not on reality itself, but on a modelized reality !

Learning, of course, is more than being taught, because it needs motivation. I already said some words about motivation in my presentation one year ago in Brussels, and I am not going to come back on the subject, but we must not forget about it.

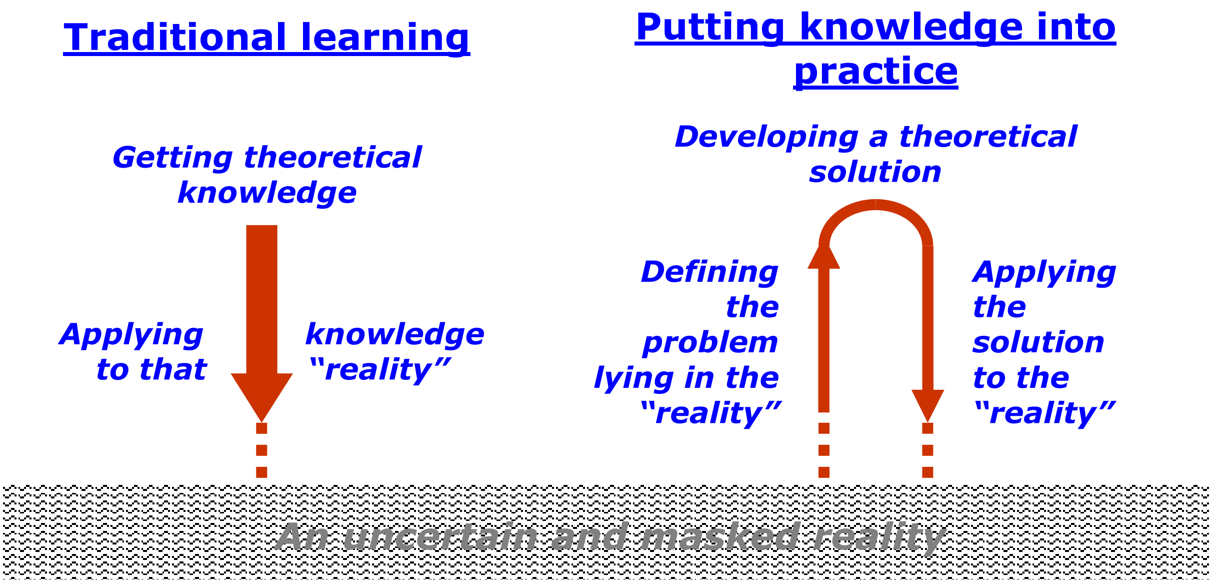
I think that the learning process is composed of two partly successive and partly concurrent stages :



- A first stage, during which the pupil or student learns how to use different forms of symbolic reasoning, including data storage in memory.
- And a second stage, during which he learns how to assemble those different forms of reasoning in order to solve “practical” problems, that is to say problems that he will meet in his personal and professional life.

It is obvious that the learning processes have to be different in the first and in the second stages.

But, independently from that, traditional “ learning ” on the one hand, and “ putting knowledge into practice ” on the other hand, are two different processes.

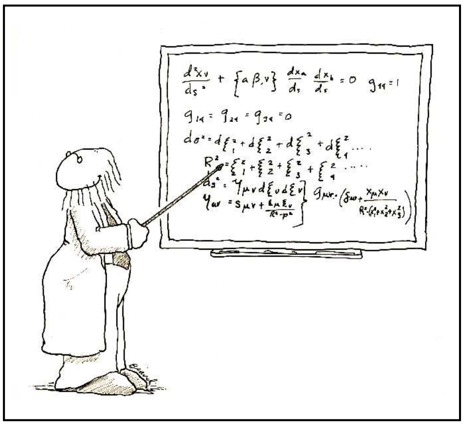


Traditional learning consists in getting theoretical knowledge – without concerning oneself about where that knowledge comes from – and in applying it to what we think reality is.

On the contrary, when putting knowledge into practice in our professional life, we first have to define the problem that is lying in the reality – in the form of cognitive models of course –, second to develop a theoretical solution by drawing the necessary cognitive materials from our reservoir of knowledge and, third, to apply and adapt our solution to the reality.

The difficulty, as I said before, is that the theoretical engineer is not in contact with the reality of the problem, neither for defining the problem nor for applying the solution : for that, he has to rely on the practical engineer !

I believe that engineers, in general, have too much confidence in their theoretical models, an attitude that they have inherited from their teachers and professors !



Yes, dear Professors, you ought to admit that the wonderful theoretical models you are teaching to your students do not always work wonderfully in reality, and you ought not to be reluctant to draw their attention to the fact that their future professional life is a much more complex reality than those theoretical models, but that your competence, generally, does not go as far as that !

Theory is fantastic as a guide for developing new ideas and projects, but it should not become a dogma ! It is quite possible that some recently developed educational models, as Problem Based Learning (PBL), could help, but I doubt they could shake that faith that we have in our theoretical models and remedy the mismatch that theoretical and practical engineers are. Both types of engineers are needed by industry and the problem is not what they are, but how they communicate with each other.

I intend now to show that a wrong learning process could hinder our way to innovation, which should be catastrophic as we know that innovation is essential for the future of Europe.

I shall begin with an example, and then develop its conclusions. It is an example of pure deductive logic, materialized by the three following clauses :

Rule :

All the beans in this bag are the same colour

Case :

The bean I have taken from this bag is white

Conclusion :

All the beans in this bag are white

Theoretically, the conclusion to which this reasoning leads is perfectly correct, but, practically, it is not worth a penny, because anybody with a practical enough mindset would ask : « ***How did you know that all the beans in that bag were the same colour ?*** ».

And there are only two possible answers to that question :

1. Either you had carefully looked inside the bag before ; and so it was a false problem.
2. Or your first premise was an assumption derived from some other deduction, and basing a correct reasoning on an uncertain premise can only give an uncertain result. In this case, **the perfection of the theoretical reasoning <u>masks</u> the imperfection of the premise and dresses an uncertain result up as a perfectly correct result** !

This is the **fundamental problem** : we have never been taught to **question the premises** of our theoretical models, because it would be a never-ending and maybe dangerous process. There are only two ways of questioning the premises :

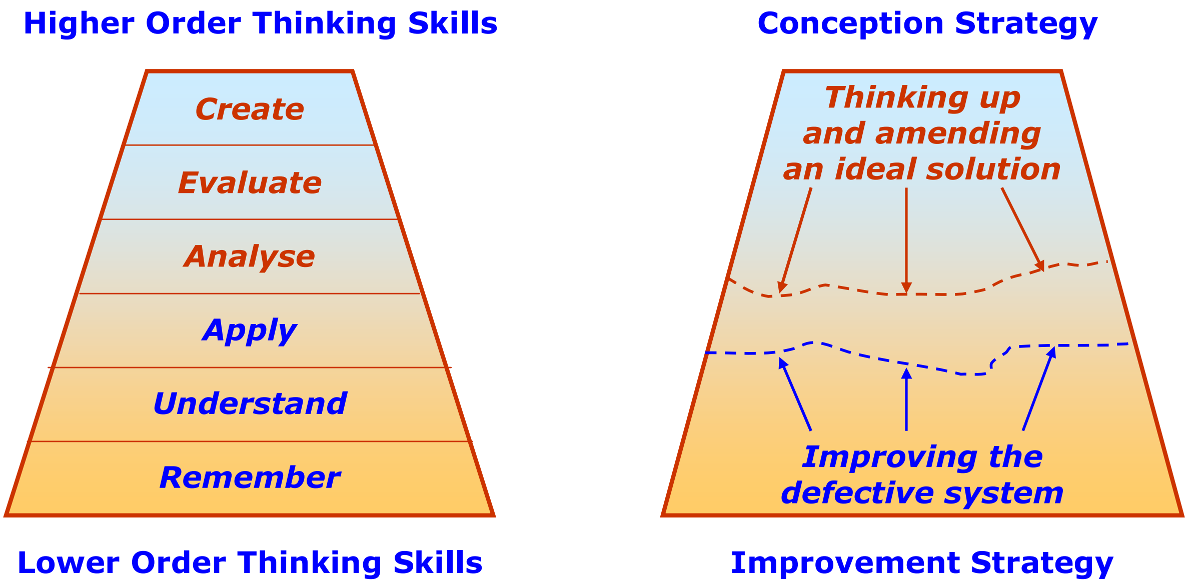
- either ***a priori***, by knowing beforehand that all premises can be questioned,
- or ***a posteriori***, when observing through contact with reality that the premises on which something has been conceived prove to be false.

The first way is obviously impossible on a large scale ; could you imagine teachers and professors saying to their pupils and students : « ***You know, all what we are teaching you can be questioned*** ». It would be " shambolic " !

Practical engineers, who are in contact with the reality of building a concrete object, or such professionals as lawyers or doctors in medicine, who are in close contact with reality through their customers or patients, usually adjust themselves to the imperfections of the premises. But, for theoretical engineers, working far away from reality, that lack of questioning can lead to fatal mistakes.

Let us now compare two pyramidal representations (see next page) :

- The pyramid at the left is simply representing BLOOM's Taxonomy of cognitive skills, revised by one of his students, Lorin ANDERSON, in 1991.
- The pyramid at the right is taken from the work of Gerald NADLER, presently Emeritus Professor of Industrial & Systems Engineering at the University of South California, who developed, in cooperation with Shozo HIBINO, Professor at Chukyo University in Nagoya (Japan), what they called Creative Problem Solving Strategy.



The core of NADLER's approach is that, when you have to remedy a problem in a given system, you can analyze the different parts of the system, find where the problem is coming from and then improve or replace the defective part. That is what they called the Improvement Strategy, based on the scientific method derived from TAYLOR's work.

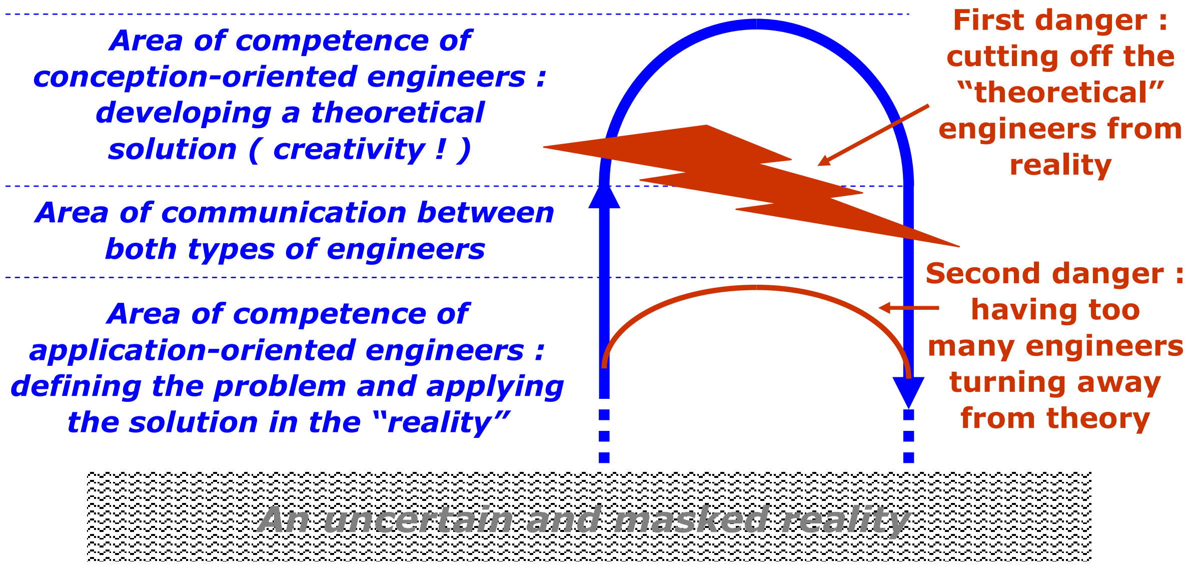
But you can also think up a completely novel, "ideal" system, performing the same function as the defective one, and "amend" it afterwards until you get something that can be implemented. This is what they called the Conception Strategy, based on creativity. It appears that, on the average, the Conception Strategy gives "better" results than the Improvement Strategy.

The comparison of these pyramids shows that, in both of them, creativity is at the top of the pyramid. We must therefore be very careful, and not use learning processes that would inhibit creativity in students' mind.

For creativity does not emerge from logical thinking alone, but from the collision of two completely different cognitive models of a situation ; it needs a broader knowledge base than what most students presently have, and the abandon of the current dominant information and incentive models that are designed to reinforce non-creative imitation behaviour.

And, when innovation is becoming so crucial for Europe's future, a decrease of creative abilities of European engineers would be catastrophic.

If I take up again the right part of the diagram I have drawn to explain the process of putting knowledge into action (page 19), we can see that there are two areas of competence – the one of the conception-oriented engineer and the one of the application-oriented engineer – separated by an area of communication between them :



This brings out the two dangers that Engineering Education has to avoid ;

1. The first danger is to cut off "theoretical" engineers from reality ; this is what industry are afraid of.

2. The second danger is to have too many engineers turning away from theory, which would be a catastrophe for Europe's competitiveness, based on the innovation capabilities of its Engineers.

5. Summary and conclusions

Now, I have come to the point where I can summarize my presentation and draw some conclusions from the various approaches that I have been using to draw some light on the subject I had to tackle.

Industrial companies and associations do not have a clear view on the subject, regretting on the one hand that their education is “ too theoretical ”, but admitting on the other hand that they need both types of engineers.

Furthermore, they do not know what they will need in the future, because they follow the laws of the market and the market is quite volatile. On the contrary, universities have to prepare their future engineers for functions that they will hold five or ten years later, and they cannot obviously follow the laws of the market !

So, I have tried to approach the question from a different, maybe unusual, angle.

I believe that engineers are to be taught how their brain works and what the advantages, but also and above all the drawbacks, of their cognitive models are. I think this is particularly important for engineers who are attracted by more theoretical approaches.

I also believe that the distinction between these two approaches is less important than fostering among engineers the emergence of real capacities for creativity and innovation, and that this requires a broader and therefore more conceptual grasp of their scientific environment, which is the exact opposite of specialization, where the engineer’s work has to lead to practical issues.

The question is not to have a less theoretical engineering education – on the contrary, evolution tends towards more abstraction and more complexity – but to make students aware of the difference between models and reality, between the map and the territory, and to offer them occasions when they can experiment that difference and realize that, nevertheless, the theoretical models they have learned are the best tools to solve real complex problems.

It remains that there is a problem of communication between conception-oriented and application-oriented engineers, but I think it is up to industry, not to university, to find a solution to that problem, for instance by using the results of the theory of loosely coupled systems.

This concludes my presentation. Thank you for your attention.

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Main references

1. **ANDREWS Tim G.**, University of Strathclyde, " ***The problem with knowledge : a temporal orientation perspective on the theory-practice divide*** "
2. **BALMONT Michel**, " ***Le masque*** " (« The mask »)
3. **BOUDON Raymond**, Professor, University of Paris-Sorbonne, " ***L'art de se persuader des idées douteuses, fragiles ou fausses*** " (« *The art of convincing oneself of doubtful, shaky or false ideas* »), Fayard, 1990.
4. **BUSINESSEUROPE**, " ***Expectations on European cooperation in Vocational Education and Training*** ", Position Paper, 15 October 2010
5. **BUSINESSEUROPE**, " ***Universities and Businesses : key partners for a competitive Europe*** ", speaking notes of Mr **Daniel CLOQUET**, European Parliament Seminar, 3 February 2010
6. **COLLINS Tom**, Professor National University of Ireland, " ***Challenges for the Education System in a Knowledge Economy*** "
7. **DIZAMBOURG Bernard**, " ***L'enseignement supérieur : une compétition mondiale ?*** " (« *Higher Education : a worldwide competition ?*»), in Revue Internationale d'Éducation – Sèvres, n° 45 – Septembre 2007
8. **EFT**, Engineers and engineering, vocabulary
9. **FABRI Marc**, **GERHARD Michael**, **HOBBS Dave J.** and **MOORE David J.**, Leeds Metropolitan University, " ***Perceiving the Others : Cognitive Processes in Collaborative Virtual Environments*** " in Proceedings of 17th Eurographic-UK Conference, April 1999, Cambridge, UK
10. **FISCHER Karin** & **WILHELM Ian**, " ***The future of American University*** ", the Chronicle of Higher Education, 21 June 2010
11. **GARUD Raghu** & **RAPPA Michael A.**, " ***A Socio-cognitive Model of technology Evolution*** "
12. **GOLA Muzio M.**, Professor, Politécnico di Torino, " ***The ALFA-Mirro Q.A. Framework : principles, structure and tables*** ", 37 Congresso Brasileiro de Educação em Engenharia – COBENGE 2009
13. **HEDGE Alan**, Professor, Cornell University, " ***Behavioural and Cognitive Methods*** ", January 2010
14. **HENNEGERG Stephan C.**, **ROHRMUS Daniel** & **RAMOS Carla**, " ***Sense-making & Cognition in Business Networks : Conceptualisation & Propositional Developments*** "
15. **HERMANUBIS**, " ***Le symbolisme du masque*** " (« *The symbolism of the mask* »)
16. **HILTUNEN Elina**, " ***Organizational Futures Learning*** ", NOKIA, 2008
17. **IBM**, " ***The Enterprise of the Future*** ", Global CEO Study 2008
18. **KLEINSCHMIDT Andreas**, SIEMENS AG, " ***The University of the Future*** ", Publications of the Future, Fall 2006

19. **MACKWORTH Alan**, University of British Columbia, Vancouver, Canada, “ ***Recycling the Cycle of Perception : a Polemic*** ”, in Proc. AI 2002, Calgary AB, May 2002

20. **MURRAY Art** & **LESHER Jeff**, “ ***Transforming your organization into an Enterprise of the Future*** ”, Applied Knowledge Science, 6 August 2010

21. **OPKAPU Joseph Sr.** & **MURRAY Art**, “ ***Building the University of the Future today*** ”, KM World, 3 July 2009

22. **PAGIDAS Alexandros**, “ ***University of the Future*** ”, BIL Conference 13-14 February 2009

23. **TEICHLER Erich**, Professor, University of Kassel, “ ***The Changing Professional relevance of the Bachelor Degree*** ”, contribution to the Seminar “ Enhancing European Employability ”, Swansea, 13-14 July 2006

24. **TEICHLER Erich**, Professor, University of Kassel, Higher Education in Knowledge Society, Beijing Forum 2010

25. **WALKER Jim**, “ ***Confusing the Map for the Territory*** ”

26. **WEICK Karl E.**, Professor, Cornell University, “ ***Educational Organizations as loosely Coupled Systems*** ”

27. **WILLEY T.**, University of Derby, “ ***A model for adaptive design*** ”

28. **XIAO Yan**, University of Maryland, & **MILGRAM Paul**, University of Toronto, “ ***Toward an Understanding of Field Studies*** ”

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