Dr. Ali KILIC

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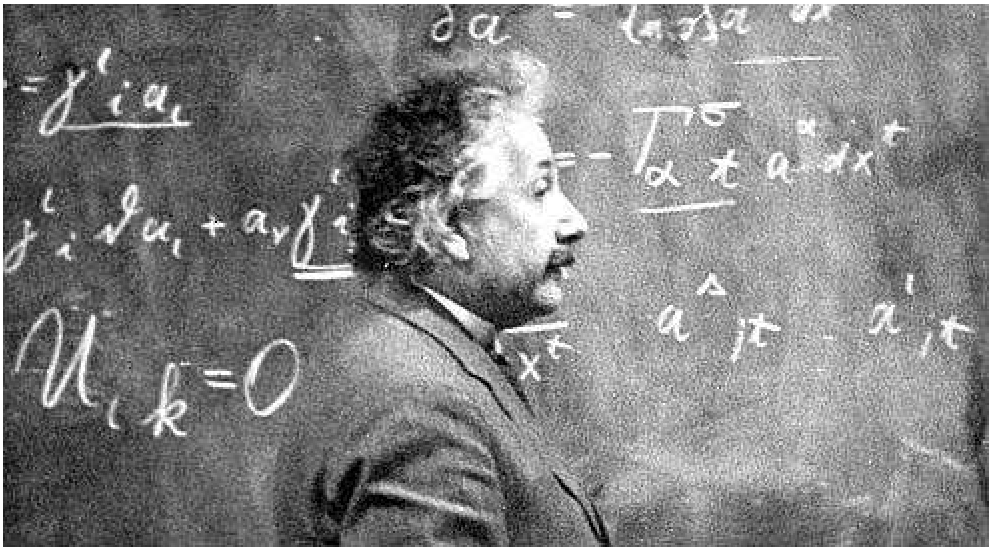
Imagination and Intuition in the sciences



Academy of Sciences of France and Institut of the France - Fondation Simone and Cino del Duca Deutsche Akademie der Naturforscher Leopoldina Foundation Khor, Ecole Normale Superieure Paris, Deutscher Akademischer Austausch Dienst, organized in Paris a symposium on 7-8 November 2008 on the theme Intuition and the imagination in the sciences..

Everyone knows the story of Newton and the fall of an apple that would suddenly open their eyes to the universal gravitation. Or Archimedes, which plunged into its bath, exclaimed "Eureka!" And discover the famous principle that bears his name. These are obviously legends. But the share of imagination and intuition in the world of science and discovery is real. And to better understand its importance, a symposium meets from Friday morning for two days, dozens of prominent researchers, French and German, the Foundation Simone and Cino del Duca, under the auspices of the Academy of Sciences and of the Academy of Moral and Political Sciences. And we can say that imagination is not just for poets or, conversely, that science is also poetry and intuition. "This conference has two objectives. First, to offer a unifying theme through a meeting transdisciplinary, says academician Pierre Buser, one of the initiators, with Claude Debru, also academician of the symposium. Almost all disciplines will be represented. The second objective is to deepen all that the history of science can give us in the current period of the scientific process. "[1]

[1] Figaro le 07-11-2008

The introduction was made by the academician Pierre Buser[2] on the following question ***unconscious in discevery*** Academician Peter Buser think that in our time Two modes of knowledge of reality exist, the discursive one, that only reaches reality through concepts and reasoning, and the intuitive one, that directly brings knowledge into consciousness. Intuition has been described by many philosophers and outstanding theorists in the previous centuries,. It is also since long that philosophers became convinced that there exist a mental activity besides (or outside) the conscious one. The list could be long of precursors in this line, who in a way or another, mentioned the unconscious or "deep" mind : Galien, Plotin, Augustin, Thomas d'Acquin, Paracelse, Böhme, Shakespeare, and then of course Descartes. It has often been said that the concept of unconscious processes " was a conceivable idea around the 1700th century, became an idea of the moment around he 1800th one, to finally become an operant idea in the 1900th ". Since the 17th century, the concept of an unconscious has become almost unavoidable with Leibniz, Maine de Biran, Hegel, von Schelling, von Hartmann and many others since. Interestingly, Fichte is probably one of the first philosophers to have clearly introduced the concept of the unconscious, developing the idea of an intellectual intuition, showing how this function can be conceived in the tradition of rational psychology. It is only somewhat later that the importance of unconscious mechanisms has appeared in the psychopathological field, becoming at the turn of the 19th century the clinical approach termed as psychoanalysis, with Freud, Jung and so many others. This analytical unconscious became considered as a major agent governing mind processes and behavior and, as a consequence, masking and putting aside the intellectual intuitive unconscious processes, those in the line of many pre-freudian philosophers. The latter unconscious, that one may term "cognitive", has now gained ground, being often suggested to play an essential role in scientific research and theorization. One of the domains where this class of intuition has been intensely suggested to be active is mathematics. In the late 19th a group of mathematicians, initially lead by Poincaré, later on by Hadamard, then by the Dutch mathematician Brouwer (1886-1966), and more recently by Jean Largeault, Laurent Schwartz and our colleague Alain Connes, all developed arguments in favour of intuition in mathematical discovery and even reasoning. Against them were of course Hilbert (1862-1943) and many others who argued in favour of the formalist anti-intuitionist position. To designate this unconscious intuition, an often used term is "incubation", one of the four proposed stages of creativity, together with preparation, illumination and verification. As strongly emphasized by Hadamard, "that those sudden enlightenments cannot be produced by chance alone is evident; there can be no doubt of the necessary involvement of some mental processes unknown to the inventor, in other words of an unconscious one".

My friend Jean Piere Kahane[3] and Academician and the greatest mathematician of France, member of the my Party, has made his presentation on the theme A Quotes From CONDORCET, NUMBERS, LINES AND IMAGINATION; According to Academician Jean Pierre Kahane, In public

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[3] **Jean-Pierre Kahane**, Professeur émérite, Université Paris-Sud-Orsay, Académie des sciences.

opinion, and also in the official instructions, is associated with mathematical rigor more often than the imagination. However, in the creation mathematical rigor and imagination are focused in specific ways. What is it in education? Two sentences of Condorcet, in his "speech on mathematics" indicate an access road: "The first concepts of mathematics should be part of children's education. The figures speak lines and more than previously believed usually their imagination emerging, and it is a sure way to exercise without misplaced. "You put these phrases in parallel with other languages, or from not in the same direction, and will attempt to identify suggestions for the time present.

Académician Jean Pierre Kahane and Prof Claude Debru

Professor of Philosophy at the Department of Philosophy at the Ecole Superieure de Paris **Claude Debru**[4] presented his briefing following ***IMAGINATION AND REASONING: CLAUDE BERNARD'S RESEARCHES ON THE ACTION OF CURARE***

Claude Bernard started experimenting with curare in 1844, at a time when almost nothing was known on the mode of action of this substance. He explored almost unknown physiological territories, and continued his experiments, projects and reflections on this subject until his death in 1878. His experiments are generally considered as laying certain foundations of modern pharmacology. They can be pictured as a mixture of powerful and strongly anticipatory formulations, and of interpretations which would never be confirmed. They are good examples of the ambiguous role of imagination in physiology. The historian of medicine Mirko Grmek made a detailed study of this material. More recently, a new study of the whole set of Bernard's manuscripts on curare was started, using the techniques of artificial intelligence applied to textual genesis and to modes of experimental reasoning. In the present contribution, we will study the role of imagination in the so-called « experimental reasoning », as

[4] **Claude Debru**, *Professeur, Ecole normale supérieure (Paris), Académie des sciences.*

well as particular modes of Bernard's imaginative faculty with help of later distinctions (proposed by Wundt or Ribot) regarding the varions forms of imagination in the sciences. According to Ribot, creative imagination in arts and sciences finds its origin in motor elements linked to images. It has also an unconscious dimension, often noticed by Bernard himself. It can be intuitive and spontaneous, of combinatory and discursive. Claude Bernard's researches offer numerous examples of these two types: the feeling, the intuition, creates the « experimental idea » ; the combinatory imagination creates its numerous forms and variations. Active imagination (Wundt) creates schemes of actions, which are found quite frequently as drawings in Bernard's laboratory notebooks. At the same time, Bernard had an acute awareness of the fragility of theoretical hypothesis. His researches on the mode of action of curare, his reflections and discussions, which he never considered as entirely settled, the ideas he proposed on the basis of his powerful imagination, far from being really confirmed, are good examples of this fragility of physiologica investigation dealing with almost unknown phenomena.

The creative experience was considered by Academician **Hans-Jörg Rheinberger** [5]**on** ***The Creativity of the experiment*** This paper is concerned with the experimental exploration of the unknown. Itcharacterizes scientific practice as a process of the production of unprecedented events. Such events happen, in the context of modern science, in experimental systems. They can be addressed, with Gaston Bachelard, as „cultures of emergence." The French molecular biologist Françis Jacob has characterized such systems as "machines à fabriquer de l'avenir". The question to be asked and answered is how the new is made to happen in the sciences. Whereas in analytical philosophy of science, the "context of justification" of knowledge is center stage and the "context of discovery" is marginalized, the kind of historical epistemology that I pursue here moves the latter into the foreground. I will illustrate my considerations with an example from the history of molecular biology. It shows how experimental systems evolve over time in relatively unbroken material continuity, and yet allow for major re-conceptualizations to happen.

Positivistic imagination: Ernest Mach's topics of scientific presented By Gereon Wolters[6] There are two basic competing approaches to science, the Enlightenment and the Romantic approach. The Enlightenment approach (which is related to "positivism") regards science as a rule governed, discursive enterprise that is *universalist* in the sense that in principle everybody can learn its procedures and that its results hold for everybody. The Romantic approach (which is related to "intuition"), however, relies not on determinate, universalizable procedures but rather on individual intuition. Its results are relative to certain persons or at most to a certain culture. They are, in other words *particularist*. In the history of science the Enlightenment approach is represented by standard science, whereas clear traces of the Romantic point of view can be found in Nazi science as well as in the "romanticism on the left" in the second half of the last century. These days Romanticism it is present in many "green" conceptions or etter, misconceptions, of science..

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[6] **Gereon Wolters**, *Professor, Universität Konstanz, Deutsche Akademie der Naturforscher Leopoldina*

The most perspicuous example of the Enlightenment approach in philosophy of science was logical empiricism, whereas the present Romantic approach was inaugurated by Paul Feyerabend's *Against Method* (1979), and has found most variegated followers, e.g. in the so called Strong Programme in the Sociology of Science.

Mach's philosophy of science appears as a continuation of the enlightenment approach, which avoids the one-sided algorithmic conception of methodology that is attributed to logical empiricism. Mach, rather, regards scientific discovery as not following strict rules but, what I would like to call, "topical" points of view, found in the history of science: such topics of scientific research are: analogy, simplicity, continuity, abstraction, and paradoxes.

I think the exhibitions "the scientist was presented by **Roger Balian**[7] on Quantum Physic conflicting with intuition. Since Galileo, deeper understanding of physical reality often contradicts everyday's intuition. This trend has become dramatic a century ago, rendering modern physics abstruse to the laymen. The scientist can exert his intuition and his imagination within an elaborate mathematical language, but it is impossible to translate his ideas faithfully into ordinary language; this difficulty may be one of the causes of the present tarnish of the image of science. A first shock was brought in by relativity, which revolutionized our conceptions of space and time. Quantum physics presents even more counter-intuitive features. We have been led to represent physical quantities, such as the position or the velocity of a particle, no longer by ordinary numbers but by "observables", mathematical objects which may take only some discrete values and which belong to an algebra. If two such observables commute (AB=BA), they are compatible: both may take well-defined values. If they do not commute (AB.BA), they cannot be measured nor even specified simultaneously: each of them presents statistical fluctuations which must be larger than some lower bound (Heisenberg's inequality). Thus quantum physics, our most fundamental description of nature, is an irreducibly probabilistic theory. Its predictions do not refer to a single system, but to a statistical ensemble, and the observer cannot be completely disregarded.

Moreover it may involve aspects which are apparently contradictory. For instance, microscopic objects behave both as particles and as waves, each of these descriptions being blurred with probabilities. We will discuss the so-called GHZ paradox, due to Greenberger, Horne and Zeilinger, which exemplifies the most troublesome conceptual feature of quantum physics. Indeed, it baffles not only intuition, but also current logics. It deals with a physical system made of three correlated particles. Various observables, A1, A2, A3, B1, B2 and B3=B1B2, which we do not need to specify here, can be measured on such a composite system. Each of them may take discrete values a1, a2, a3, b1, b2, b3 equal either to +1 or to –1, and we have b1b2b3=1. Consider now a statistical ensemble of systems, all prepared identically in such a way that A1B1=A2B2=A3B3=+1, through a control of the latter three products. (This is

[7] **Roger Balian**, *Conseiller scientifique, CEA (Paris), Académie des sciences*.

possible because they are compatible.) If then we measure A1 and B1, we will always find a1=b1, either with a1=b1=+1 or with a1=b1=–1; likewise for a2=b2 and a3=b3. Since b1b2b3=1, we are tempted to infer that a simultaneous determination of the values a1, a2 and a3 of A1, A2 and A3 (which are compatible) should verify a1a2a3=1. However both theory and experiment provide in all cases a1a2a3=–1. In fact the three statements a1=b1, a2=b2, a3=b3 are true, but only separately. We are not allowed to make a logical reasoning based on a simultaneous consideration of A1 and B2 because they do not commute. No calculation, no experiment can simultaneously provide values for a1 and b2. Hence, we cannot regard as true together the statements a1=b1 and a2=b2, although they can be checked by separate experiments. Each one is true, but their union is meaningless. The truth of quantum statements is contextual, in the sense that we can draw conclusions by putting together several of them, only if theory allows us to imagine thought experiments in which they might simultaneously be checked. Quantum mechanics does not provide truths about objects per se, although it is a perfect tool for making (statistical) predictions. Its logics, as well as its probabilities, obey rather shocking new rules.

Prof.Yves Jeannin[8] has raised the fundamental question of the Torah knowledge of how to design, ***Analysis, Build and provide in Chemistery*** « I write in my brain ». By these few words, the french novelist Jean Jacques Rousseau in the eighteenth century expressed the power of imagination. To build up new developments on the basis of knowledge is a precious faculty of human beings, this is imagination. To guess about fruitful developments in an unexplored field is another capacity of human beings, this is intuition. Those two valuable properties of human brain are very helpful for chemists as well as for other scientists. A few examples of the role of imagination and intuition will be dscribed ; it resultetd rarely in errors but much more often in real milestones. The theory of phlogistics met a considerable success at the time it has been eveloped although later on Lavoisier demonstrated that it was wrong. The discovery of rare gasses occurring in air is a remarkable example of putting together logic and intuition. The chemical route to catenanes, molecules looking like chains, is the result of a very imaginative process. The idea of the nylon synthesis and then the foreknowledge of its application and of its present industrial development demonstrate the fascinating impact of imagination and intuition.

One of the issues of the phenomenology of the epistemology of logical positivism was raised at the Symposium on Inductivism, hypothetico-deductivism and scientific discovery **by Martin Carrier[9]**

The demise of a logic of discovery has created problems for philosophical accounts of confirmation, namely, a more pronounced emergence of underdetermination. Hypothetico-deductivism entails a liberation of creativity which goes along with an increase in the difficulty in capturing empirically the entities and processes assumed within the theory. The loss of empirical grip

[8] **Yves Jeannin**, Professeur émérite, Université Pierre et Marie Curie (Paris), Académie des sciences.
[9] **Martin Carrier**, *Professor, Universität Bielefeld, Deutsche Akademie der Naturforscher Leopoldina.*

needs to be compensated by inserting novel conceptual elements in philosophical accounts of scientific confirmation. In particular, epistemic value assume a role in such procedures which is analogous to that played by the requirement of inductive ascent within the inductivist framework. Such reflections about the general relationship between accounts of scientific discovery and theories of confirmation are made more tangible by analyzing examples from the history of science.

It is interesting to écoueter on our Colleague Bertrand Saint-Sernin[10] On Classic design of the interaction of minds. For Bertrand Saint-Sernin, In The ***Banquet***, Socrates notes that the knowledge would be more easily if there were between minds a bit of wool "which, as between two cuts unevenly full, put the liquid in the fuller than what is less. Kant, in the Critique of wisdom, takes up this issue and are two cases very different: the scholars and poets. Only the first, he says, leave enough traces of their thinking so that we can save our steps in theirs and even go further they have developed themselves. Imagination, at the age classic, and until today, has seen his role increase: First entrusted with a representative role, she became a translator, then engineer. The current design of the interaction of minds By the early 1940s, major changes in the form classical rationality. 1 <No more scientist is able to dominate a discipline or even a theory. 2 <Major scientific programs and technology involving multiple disciplines and technologies. 3 <The implementation of projects involving players not only as individuals but communities.

The nature of the interaction between minds change: 1 <Each scientific in its specialty, operates as the classical age. 2 <When he leaves his specialty, it deals as truths, proposals that can neither establish nor prove himself It is therefore trust their colleagues in other disciplines, knowing that even if it wanted, he could not turn his belief into knowledge. The issue of the strand of wool (Wollefaden) today Unlike the classical theater, the unity of place is no longer required: the Scientists away by the hundreds or thousands of miles, working concert. It discerns the circumstances that lead to such developments. It was more difficult to see what, in the form of scientific exchanges, has changed. How to discover this strand of wool? At first glance, one can discern three tracks:

1-neurophysiologist ask if they can teach us about how which can improve the interaction of minds to make their collective action more productive;

2-Observer research institutions and educational work well and learn from their example;

3 -do as the three protagonists of the Laws of Plato, when they look how to build a city of good new laws.

[10] **Bertrand Saint-Sernin**, *Professeur émérite, Université de Paris IV-Sorbonne, Académie des Sciences morales et politiques.*

A scientific discovery inspired by the mythology the case of the multiplier installed Schweigger by Andreas Kleinert[11] A scientific discovery inspired by ancient mythology: Schweigger's invention of the multiplier, the first instrument for measuring electric currents. For Andreas Kleinert The physicist Johann Salomo Christoph Schweigger (1779 – 1857) is best known as the inventor of a device for measuring weak electric currents, the so-called multiplier. As early as in November 1820, he anticipated Faraday's electromagnetic rotation apparatus by suggesting the realization of a permanent mechanical rotation based on Ørsted's discovery of electromagnetism. In his research on electricity and magnetism, Schweigger was guided by the idea that electromagnetism had already been known in antiquitity. Being trained as a classical scholar, he was familiar with Greek and Roman mythology, and he believed that physical knowledge was hidden in ancient myths. According to Schweigger, the Dioscuri Castor and Pollux were symbols of the electric poles, and a picture representing Castor, Pollux and dancing water nymphs served him as a guidance for the construction of physical devices like the multiplier and a rotation apparatus. Neither by his contemporaries nor by posterity, Schweigger's opinion about physical knowledge in antiquity was taken seriously. Nevertheless it is remarkable that such a strange speculation led to far-reaching scientific results, the multiplier being a basic requirement for quantification in electricity. Thus Schweigger's physics is a convincing evidence that logical reconstructions of scientific developments are highly problematic.

The scientific and philosophical element were studied by mathematicians and by **Étienne Ghys,[12] on The mathematical space as a network** Frequently, mathematicians compare themselves to explorers discovering unknown territories. This is somehow analogous to searching the best itinerary between two cities However, usually mathematicians don't even know where they want to go and they basically want to discover « interesting things ». Again, this is analogous to the google search engines which try to classify websites according to some « relevance ». In this talk, I would like to describe some of the strategies used to analyze the gigantic cyberspace network. I would also like to discuss, very superficially, the question of the significance of this kind of analogy when one tries to describe the strategy of a mathematician at work.
Mathematical creativity And transgression limitation or restriction was the statement of mathematician

For **Eberhard Knobloch** There is a close relationship between mathematical creativity and the transgression of limits or restrictions. Often the creative mathematician is able to imagine objects that are seemingly senseless or impossible (imaginary numbers, divergent series, undimensional spaces, actually infinite sets etc.). He disregards seeming necessities (the sum of the angles of a triangle is equal to two right angles). He is able to imagine

[11] **Andreas Kleinert**, Emeritus Professor, Martin Luther Universität (Halle-Wittenberg), Deutsche Akademie der Naturforscher Leopoldina.
[12] **Etienne Ghys**, *Directeur de recherche au CNRS, Ecole normale supérieure (Lyon), Académie des sciences.*

mathematical area that is strictly forbidden or inaccessible, that has never been entered before or that does not exist (as it seems). "The essence of mathematics resides in its freedom", as Georg Cantor stated in 1883. The lecture will illustrate this statement by two case studies: 1) the emergence of non-Euclidean geometries, 2) the solution of the Basel problem (summation of the reciprocal square numbers):

1)The parallel problem is the question whether the true parallel postulate is a theorem of absolute geometry. The thesis will be proven that - contrary to the usual historiography - the solution of this problem is neither sufficient (Aristotle, Euclid) nor necessary (Reid) for the emergence of non-Euclidean geometry.

2) Euler was able to solve the famous Basel problem because he did something forbidden, He considered infinite power series as algebraic equations of infinitely large degree.

Yves Meyer spoke of Fiction , Art and Mathematic prophets. For Yves Meyer Goethe was fascinated by the beauty of crystals; he collected throughout his life. Carl Friedrich Naumann, a professor of mineralogy in Leipzig offered a Gœthe copy of its "Summary of crystallography." Goethe replied on 18 January 1826 to thank him: Your important work I did, and I read and reread with pleasure until the Page 45. But what happened there on page 45? Gœthe Why could not he continue his reading? We frankly confess: I am absolutely unable to operate by signs and figures in any manner whatsoever, and to use this language in which spirits are so eliteeasily. As Goethe said, mathematicians have created a language that is own and in so doing have built a fantasy world, a perfect beauty and a rigor impeccable logic, which was often decried. However in this language that the laws were written in crystallography. Gœthe regret. Without leaving the crystallography, we will show that mathematicians are sometimes prophets but they are sometimes outstripped by the artists. Goethe would have so loved what I will say about quasi-crystals, as the Science and Art, East and West, timeliness and the Middle Ages it together. It all started by a geometry problem posed by Johannes Kepler and dating back to Aristotle in fact: Are there any paving exact space using only a finite number of "building blocks" and not are not regular? The forms used bricks are finite, but each form, there are an infinite number of identical bricks. One thinks of mosaics where small stones fit exactly. The "Penrose tilings" invented in 1976 by the mathematician Roger Penrose, solve this problem. These are geometric figures paradoxical and difficult to discover. The existence of these pavements is demonstrates reasoning and not by a computer calculation. A piece also it may be extended, a paving Penrose does not, if we do not know the rules of construction, continue the design of quasi-crystal. Eight years after the work of Penrose, these quasi-crystals were found in nature. The paradoxical atoms in some alloys exactly obey the rules established by Penrose in the construction of pavements. The reference is an article of D. Shechtman, I. Blech D. Gratias and J. W. Cahn, entitled Metallic Phase with Long-Range Orientational Order and No Translational Symmetry, Phys. Rev. Lett. 53, 1951-1953 (1984). D. Shechtman and employees have not been influenced by reading the work of Penrose. They do unfamiliar; their discovery thus met with strong opposition because it seemed violate the laws of crystallography. Finally two years ago, physicist Peter Lu of Harvard noticed on the wall of a madrassa in Bukhara, Uzbekistan, a geometric pattern identical to that of a quasi-crystal. The building dates the fifteenth century. Peter Lu today consult books written by artists Muslims from the Middle Ages. It seeks if some geometric patterns that are proposed comply with building regulations established by PenroseI can not conclude, as the meeting between the Art of Islam, mathematics and Chemistry is lovely, strange and therefore asks to be discussed.

Balancing vision and product requirements Crucial Challenges in Engineering Design présented by **Walter Michaeli** [13]Engineers create and design physical objects which shape and change our world and make our lives easier. – Engineers have been around for 6000 years already.Engineers have visions and translate these into real objects – into technical artefacts. In the first instance there is always an idea, a determination, even an obsession to find a solution. However, in many cases engineers did not generally understand the full implication of what they were inventing. This is illustrated for the motor-propelled aircraft of the American Wright brothers and for the German Rudolf Diesel and his fuel-driven compression-ignition engine. Engineers have generally been in a contractual relationship and still are today. They have to translate clearly defined specifications into technical products and processes. Doing this they mostly remain in the background doing their complex and responsible job. Work engineers must always critically reflect back their own ideas and visions from the given requirements and specifications; they must accept compromises and in some cases, they must painfully renounce their own wishes, ideas or visions for the sake of the overall solution. Maintaining this balance, while obtaining a functioning and affordable product at the same time, is the critical challenge that is involved here. It is shown how engineers cope with this challenge in engineering design of products. The systematic design procedure considering creative and routine elements in product design is described and explained. A key element of this is the "requirements' list" which states all the demanded and wished functions and properties the final product has to fulfill. In a systematic and methodological way ("planning phase","conceptual design","embodiment design","elaboration") alternative design solutions are found and finally evaluated for further consideration, materialisation, and use. During all this, achieved properties and especially costs play a significant role. Engineers always have visions but they have to be realistic in accepting also existing constraints and given limitations.

The reality beyond the imagination and purpose of the briefing by Pierre Lena.[14] Prof. Pierre Lena think In astronomy, questions about the universe have been formulated as soon as this science was born, 25 centuries ago at least, in the West as in the East. The proposed answers were largely marked by myths, as possible verification, or event the idea of verification, were lacking. In this science where it is impossible to directly experiment on celestial bodies, observing them is crucial. Observation is indeed stimulated or limited by the techniques available at a given time, but also by the questions which can be formulated, i.e. by the available representations and theories. This constant

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interplay between an objective knowledge of the sky and theoretical thoughts has marked, and still does, the development of astronomy. How, in such a specific context, do new ideas pop up ? Are they stimulated by unexpected observations, becoming possible thanks to technical progress and not understandable in any existing conceptual frame ? Or on the contrary, are they the result of a new theoretical concept, which fosters new observations, or even instruments, and becomes confirmed ? Each of these cases has happened during history, and could be well illustrated. But the most astonishing is the fact that, in either case, the discovered reality is always beyond what imagination had conceived… We shall develop an example of a remarkable instrumental concept, the Young holes, which has had since 1802 a considerable fortune and fecondity in physics and astrophysics, despite (or because ?) its incredible simplicity. To analyze how imagination and intuition may have been stimulated by this concept is difficult, but the contribution shall try to explore the question.

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